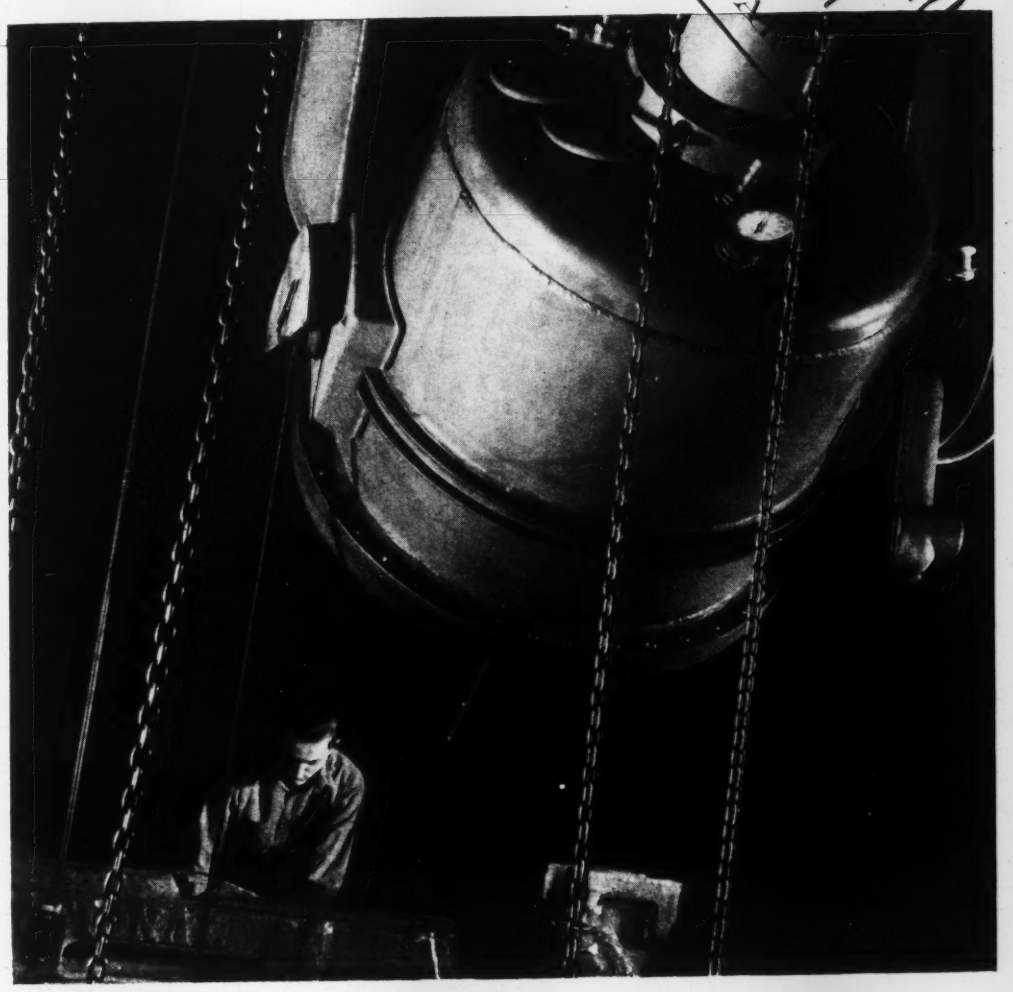
Instruments

THE MAGAZINE of MEASUREMENT and CONTROL

INCLUDING THE *Journal of the Instrument Society of America*

AND THE *Journal of the Southern California Meter Association*

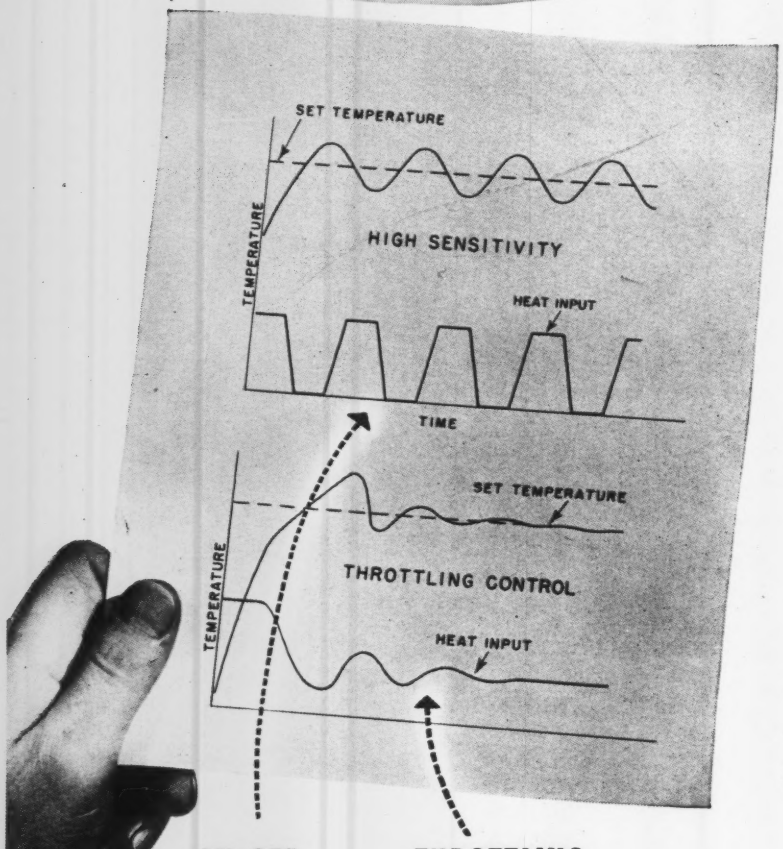
1951



FOR *Consistent* CONTROL

Choose Characteristics to

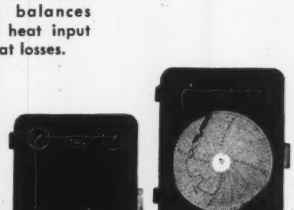
FIT YOUR CONDITIONS



ON-OFF
The simplest control, excellent for ordinary needs. Fastest heating to set temperature.

THROTTLING
Closely holds set temperature, balances continuous heat input against heat losses.

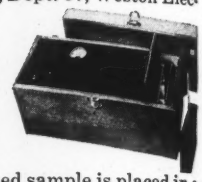
Furnaces heated by oil, gas or electricity can be accurately controlled with TAGliabue Pneumatic Controllers. On-off types give fastest heating; throttling types accurately balance heat input against losses to prevent overshooting or hunting. Both utilize an 18 p.s.i. air supply to operate diaphragm valves or power relays. Companion models control pressures along the same principles. Available as Indicating Controllers or as Recorder-Controllers. Write today for technical literature.



TAGLIABUE INSTRUMENTS DIVISION
WESTON ELECTRICAL INSTRUMENT CORPORATION
614 Frelinghuysen Avenue, Newark 5, New Jersey

Dielectric Moisture Meter Checks Various Materials

Moisture content of finely powdered, relatively dry, or coarse and oily materials is determined in less than two minutes with the versatile Model 8007 Dielectric Moisture Meter developed by TAGliabue Instruments Div., Dept. 67, Weston Electrical Instrument Corp., Newark 5, N. J. Operating over an extremely wide range, this meter functions without damaging the sample.



To use, a weighed sample is placed in a cell inserted in the instrument. The meter shows the material's capacitance, which simple tables convert into percent moisture. Chemicals, dehydrated foods, soaps, flours, seeds, plastic molding powders, iron ore, coal, cheese, coffee, corn, grain, dried leaf, flue dust, starch, yeast and cottonseed typify materials tested.

Weston Metal Thermometers Combine Precision, Stamina

Accurate, reliable temperature indication is given by the all-metal Thermometers manufactured by Weston Electrical Instrument Corp., Newark 5, N. J. These sturdy instruments are designed for utmost legibility and are constructed for use under severe operating conditions.

Weston All-Metal Thermometers can be supplied with the stem projecting from the back or from the bottom, top or side at any angle. Stem lengths from 2½" to 24" are standard; stems as long as 72" are available. A 3" dia. head provides a scale 6" long. Temperatures as low as —100°F. or as high as 1000°F. can be indicated. The "Max-Min" type records highest or lowest temperature since resetting. Contact making type closes an electrical circuit at an easily set value. Special models are also available.

Self-Operating Controllers Hold Precise Temperatures

Temperatures between the limits of 20 and 300°F. are accurately maintained by the line of Self-Operating Controllers manufactured by TAGliabue Instruments Div., Dept. 67, Weston Electrical Instrument Corp., Newark 5, N. J. These controllers are entirely self-contained, requiring no connection to any air or electrical power supply.

Available in styles for use on steam, hot water or refrigerant lines, TAG Self-Operating Controllers continuously adjust the supply of heating or cooling medium to maintain constant temperature despite changing thermal conditions. Typical applications include water heaters, tanks, retorts, washers, driers and pasteurizers

a Moderately Priced
A-C Vacuum-Tube Voltmeter

Five Ranges *Four Scales cover the ranges from 0.1 to 150 volts a-c (full scale 1.5, 5, 15, 50, and 150 volts).*

Accurate *± 3% of full scale on all ranges; r-m-s values of sine-wave voltage.*

Frequency Range *Without correction, up to 120Mc with maximum error of 10%. Correction curve supplied.*

Input Impedance *Equivalent input capacitance of probe is 11 μμf; with plug connectors 12 μμf; equivalent parallel input resistance 7.7 megohms at low frequencies.*

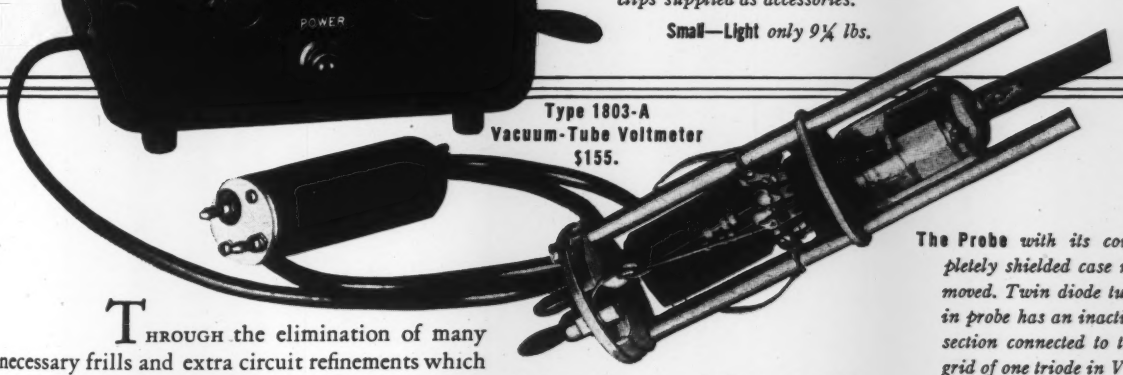
Single Zero Adjustment *for all ranges.*

Internal Calibration Control *Single adjustable resistor corrects calibration if amplifier tube is changed.*

Auxiliary Connectors *a G-R double plug, pair of 30" test leads, pair of test prods and two alligator clips supplied as accessories.*

Small—Light *only 9¼ lbs.*

Type 1803-A
Vacuum-Tube Voltmeter
$155.



The Probe *with its completely shielded case removed. Twin diode tube in probe has an inactive section connected to the grid of one triode in V-2 amplifier while active section is connected to the grid of the other triode, both sections of the amplifier being used in a balanced circuit. The balanced amplifier insures very little zero shift when line voltage varies.*

THROUGH the elimination of many unnecessary frills and extra circuit refinements which would be necessary in a meter with ohmeter and d-c circuits and scales, G-R presents this a-c vacuum-tube voltmeter with a straightforward circuit and with accuracies sufficient for most laboratory requirements at a very moderate price.

Substantially duplicating the performance of the very popular pre-war Type 726-A instrument, this new Type 1803-A Vacuum-Tube Voltmeter sells for less than its predecessor and is improved over the older model in that it is smaller, lighter, has a probe that is also smaller and completely shielded, has a single zero adjustment for all ranges and a power supply not limited to operation at a single frequency.

The probe plugs into clips on the side of the cabinet, in which position the auxiliary test leads and terminals supplied with the instrument can be conveniently attached to the input connections.

Write for Complete Data

GENERAL RADIO Company
275 Massachusetts Avenue, Cambridge 39, Mass.
NEW YORK 6 CHICAGO 5 LOS ANGELES 38

Announcing BI-ACT* Single-Adjustment of

CONTROLLER with Proportional & Reset

An inexpensive force-balance controller with proportional and automatic reset adjusted by a single knob. Particularly suited for flow applications. A logical addition to the TRANSET* Control System.

BI-ACT is TRI-ACT's* little brother. The inexpensive BI-ACT Controller has *two* control responses, proportional and automatic reset, with both adjusted by *one* knob. It is the ideal controller for dependable, accurate performance on locally mounted flow and similar control applications where it is felt that the quality of control obtainable with the three responses of the TRI-ACT Controller is not essential.

TAYLOR'S NEW BI-ACT CONTROLLER GIVES YOU:

1. Single-Adjustment of Proportional and Reset.

2. Simple stability "tune in".

3. Low cost.

Taylor's TRANSET Control System, with its three component units, is the new concept in pneumatic control that everybody is talking about. The three units, TRANSAIRE*, TRI-ACT and TRANSET, are designed to work together as a team to take advantage of each other's superior performance on all applications. Now Taylor has added the inexpensive BI-ACT Controller to extend the scope of the 3-part Transet Control System.

Write for Bulletin 98070

Taylor Instrument Companies,
Rochester, N. Y., or Toronto, Canada.

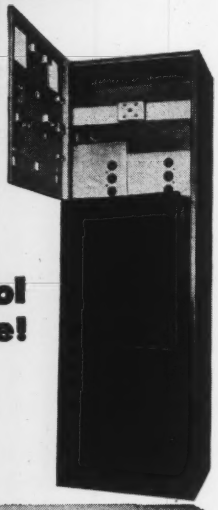
Instruments for indicating, recording and controlling temperature, pressure, humidity, flow, liquid level, load, speed, and density.

Taylor's Centennial ACCURACY FIRST SINCE 1851

*Trade-Mark

Taylor Instruments
MEAN
ACCURACY FIRST
IN HOME AND INDUSTRY

Specify
CONTROL
PANELS
by
FALSTROM



Three tier
Switchgear
Cabinet

-service on control panels is complete!

—FOR ALL PANELBOARD AND HOUSING REQUIREMENTS

You can depend on Falstrom for experienced design and expert workmanship in the building of panelboards, switchboards, cubicles, instrument panels, control centers and switchgear housings. Falstrom service includes the planning and production of distinctive, finished housings with functional qualities that assure practical economical installations. Check with Falstrom, now. Fill out and mail handy coupon for details.

FALSTROM COMPANY

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I am interested in the items checked. Please send complete information at once. →

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TITLE_____
COMPANY_____
STREET ADDRESS_____
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☐ INSTRUMENT PANELS
☐ CHEMICAL BOARDS
☐ GAGE BOARDS
☐ CONTROL CENTERS

Instruments
THE MAGAZINE *of* MEASUREMENT *and* CONTROL

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LEWIS

SELECTOR SWITCHES
FOR
RESISTANCE THERMOMETERS
AND
THERMOCOUPLE THERMOMETERS

EACH SWITCH HAS "OFF" POSITION PLUS NUMBER OF POINTS LISTED.

Points	Size	Switch Part Numbers: Thermocouple Type	Switch Part Numbers: 3 Wire Resistance-Thermometer Type
2	2″	11S2	36SR2
3	2″	11S3	36SR3
4	2″	11S4	36SR4
5	3″	10S5	37SR5
6	3″	10S6	37SR6
8	3″	10S8	37SR8
9	3″	10S9	37SR9
10	3″	10S10	37SR10
12	3″	10S12	37SR12
16	3″	10S16	37SR16
18	3″	10S18	37SR18
20	3″	10S20	37SR20
24	4″	27S24B2	38SR24
28	4″	27S28B4	38SR28
40	4″	38S2C	

(No. 38S2C is made with soldering-lug terminals)

2" SIZE

3" SIZE

SPECIAL SWITCHES

No. 37S6C2, Four "4 Point and OFF" thermocouple switches combined in one 3″ case.

No. 9S5, Single Pole, Four Point Instrument Switch in 1¼″ round case.

No. 44S4, Six Pole, Double-throw Instrument Switch in 2½″ round case, one hole mounting, ½-32 threaded bushing.

4" SIZE

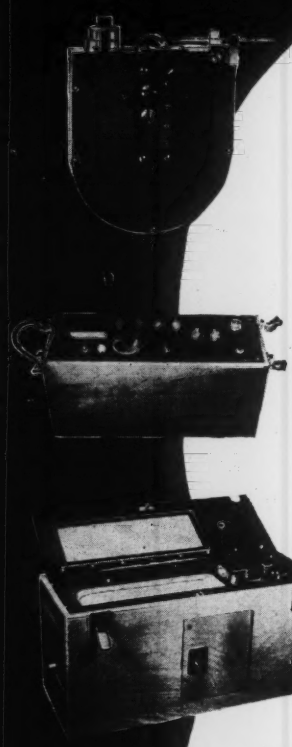
DESIGNED FOR TEST WORK AS WELL AS FOR PERMANENT INSTALLATIONS. LEWIS SELECTOR SWITCHES ARE CONSTRUCTED WITH STURDY CONTACTS OF LOW RESISTANCE AND POSITIVE DETENT. THESE SWITCHES ARE SPLASHPROOF, DUSTPROOF AND ARE BUILT TO GIVE YEARS OF SERVICE.

THE LEWIS ENGINEERING CO.

Manufacturers of *Complete* Temperature Measuring Systems for Aircraft

NAUGATUCK, CONNECTICUT

Edin instruments

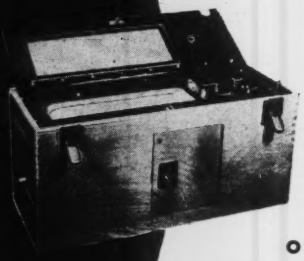


OSCILLOGRAPH GALVANOMETER

No's. 8001, 8002, 8003 and 8004 ink-writing galvanometers have sensitivities from 3.5 to 40 volts per cm., resonant frequencies from 15 to 120 cps., resistances from 1000 to 2000 ohms, frequency response up to 350 cps., and a single-jewel pivot construction. Units are designed for multiple operation up to 10 channels in a total width of 12 inches.

DIRECT-COUPLED AMPLIFIER

No. 8100 direct coupled amplifier has a voltage amplification of 13,000 with a maximum output of 70 volts. Frequency response from d.c. to 10,000 cps. is flat within 10%. Input impedance is 2 megohms; output impedance is 150 ohms. Input may range from 0.1 mv. to 100 volts. Stability is better than 0.1 mv. per thirty minutes, or 0.5 mv. per day. Attenuator is stepped for factors from 1 to 1000.



OSCILLOGRAPHS

Recorders can be supplied with 1, 3 or 9 chart speeds ranging from 0.1 mm./sec. to 250 mm./sec. See specifications of OSCILLOGRAPH GALVANOMETER for frequency range.

OSCILLOGRAPH AMPLIFIER

No. 8121 special amplifier has a time constant of 1 second, an exponential response to a square wave at high gain, input impedance of 1 megohm, and input form 0.1 mv. to 1000 volts. At low gain, No. 8121 becomes a DC amplifier with a voltage gain of 100 and an input of 10 mv./mm.

HIGH-GAIN AMPLIFIER

No. 8130 amplifier has a voltage gain of 1,000,000 and includes a built-in pre-amplifier. Frequency response is from 1 to 200 cps. Input may range from 10 microvolts to 100 millivolts. This amplifier is particularly suited for Biological studies.

Many other types of recording and amplifier circuits are available and special equipment can be assembled to meet particular specifications.

EDIN COMPANY, INC.
207 Main Street
Worcester 8, Mass.

Please send complete information on:

☐ RECORDERS
☐ NO. 8121 AMPLIFIER
☐ GALVANOMETERS
☐ No. 8100 AMPLIFIER
☐ No. 8130 AMPLIFIER
☐ ..... SPECIAL (Enclose details)

..... (NAME)

..... (NO.) ..... (STREET)

..... (CITY) ..... (STATE)

..... COMPANY ..... POSITION

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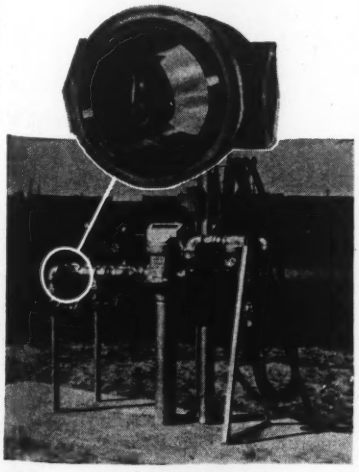
ENGINEERING News
VACUUM APPARATUS • HEAT TRANSFER EQUIPMENT • STRAINERS • CONDENSERS AND VACUUM PUMPS • OIL BURNING EQUIPMENT

BLAW-KNOX COMPANY USES SK PANEL MOUNTED ROTAMETER TO METER FILTERED OIL ON ELECTROIL FOGGER

The SK Engineering News is published quarterly in magazine form. Instrument engineers will find many of the articles on SK Rotameters and Flow Indicators of value. Have your name placed on our mailing list by writing to the Company at the address below.

SK Flapper-Type Flow Indicators indicate flow of a gas or liquid by means of a hinged flapper. They are widely used on butane-propane service to show flow or to indicate leaks. *Available from stock, this type of Flow Indicator and other types are described in detail in Bulletin* 18-*W, copies of which are available upon request.*



A typical example of the use of an SK Panel Mounted Universal Rotameter is shown in the photographs of a Blaw-Knox Electroil Fogger, front and rear photographs of which are shown above. This Electroil Fogger is used for producing a stable oil fog in a gas stream. Vaporizing the oil completely into a definite quantity of gas and suddenly cooling this vapor mixture with a large volume of cold gas causes the oil to condense out as an exceedingly fine fog. Such a fog will travel long distances in the gas main and will accomplish the following: (1) It will wet down dust deposits; (2) It will prevent drying out and dislodging of existing wet deposits; (3) It will moisten leather diaphragms; (4) It will curb internal corrosion of steel mains; and (5) It will help prevent the drying out of jute joint packing.

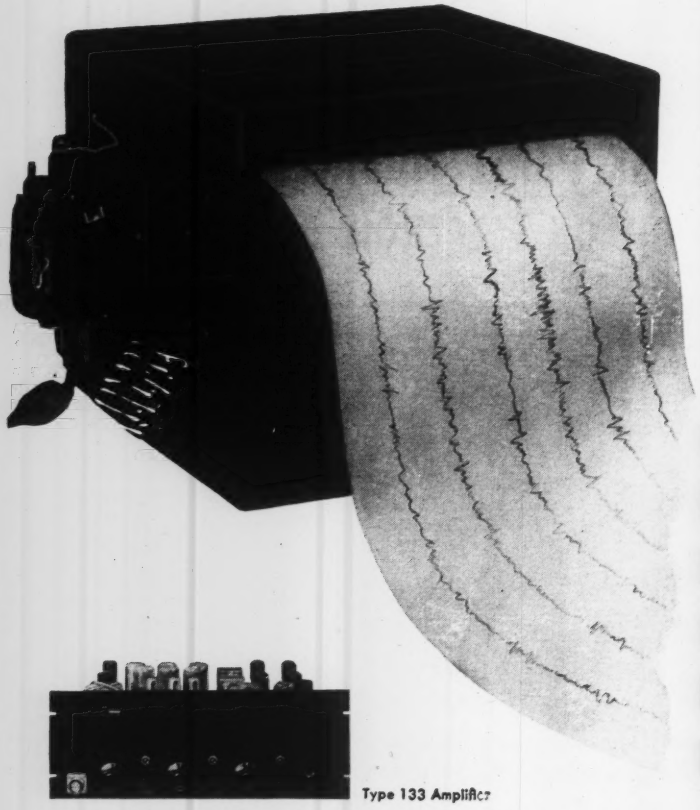
The SK Panel Mounted Universal Rotameter is used to meter the supply of filtered oil which is mixed with a controlled portion of fogging gas. The mixture produced is passed through a vaporizing coil in the heater to effect complete vaporization of the oil.

Blaw-Knox uses this type Rotameter because of its adaptability for panel mounting and its characteristic accuracy in measuring fluid flow rate.

SK Panel Mounted Universal Rotameters are available from stock. For detailed information, request Bulletin 18-*RB.*

SCHUTTE and KOERTING Company
Manufacturing Engineers
CORNWELLS HEIGHTS
BUCKS COUNTY, PA.

THE OFFNER DYNOGRAPH RECORDER



Type 133 Amplifier

drift-free d-c recording

- SPEED
- TEMPERATURE
- PRESSURE
- VIBRATIONS
- POSITION
- OTHER VARIABLES

check these exclusive Dynograph features

Pen Deflection Linearity of 1% with pen response of 1/120th of a second.

Sensitivity of 150 microvolts d-c per centimeter of pen deflection.

Stability and drift-free operation through a special chopper type amplifier.

No extra equipment needed with reluctance type pick-ups.

True Differential Input obtained through special transformer coupling.

Offner Electronics Inc., the original manufacturer of precision, direct writing oscillographs, now offers to industry the Dynograph Recorder—a direct writing, high speed oscillograph with microvolt d-c sensitivity.

Operating at approximately 100 times the speed of other industrial recorders with comparative sensitivity, the Dynograph simultaneously records many variables formerly recorded only by photographic means.

Now you can obtain a precise record of transients in the operation of various equipment through a ruggedly built, easy to maintain, versatile d-c recorder—the Dynograph.

Write Today for Bulletin L-311—Complete Specifications and Construction Details of the Dynograph

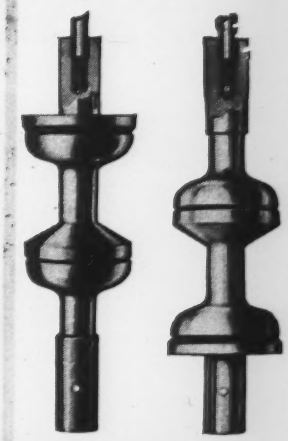
OFFNER ELECTRONICS INC.

5320 N. KEDZIE AVENUE CHICAGO, 25

COMPARE

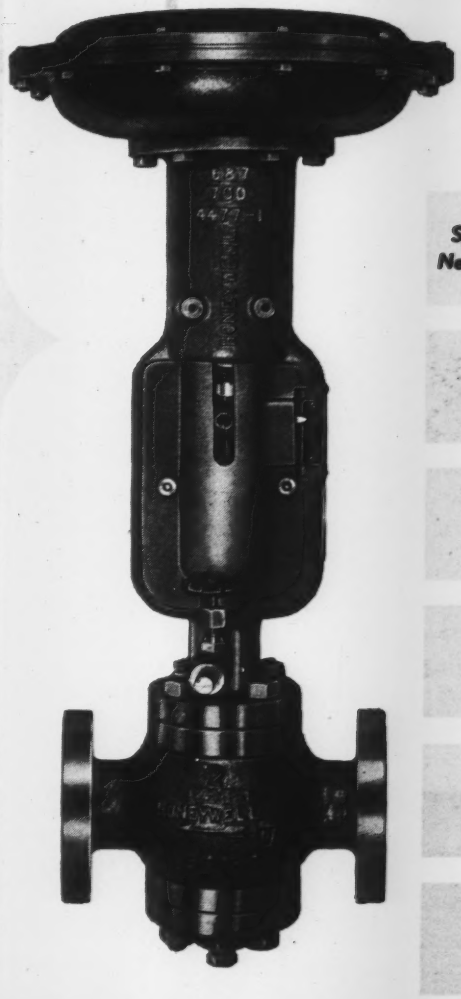
THIS FEATURE

OF THE HONEYWELL SERIES "700" VALVE



VERSATILITY

Design of plugs and bodies permits easy reversing in field. Simply invert body and plug and reattach. No extra parts or complicated adjustments required. Valve travel indicator plate is etched on both sides and need only be turned over when inner valve action is reversed.



Specially Designed Neoprene Diaphragm

Duplex Upper Stem Guide

Packless Bellows Seal

Safety Stem Lubricator

One-Piece Bonnet

Wide Variety of Discs

✱ Compare the Versatility of this valve with that of any other wide band proportional type . . . for instance, the easy reversibility of the plugs in the field.

Then check the other features of the valve . . . the Specially Designed Diaphragm, the Duplex Stem Guide, the One-Piece Bonnet, the Packless Bellows Seal, the Safety Stem Lubricator, the wide variety of discs to meet the most exacting process requirements.

Your comparison will prove that the Honeywell Series 700 has *all* of the features you look for in a fine valve.

It's available in a wide range of styles and sizes. For detailed information, write for a copy of Bulletin 700-2 or call in your local Honeywell engineer . . . he is as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 1908 Windrim Ave., Philadelphia 44, Pa. Offices in more than 80 principal cities of the United States, Canada and throughout the world.

New Bulletin 750, "Control Valve Sizing Data" is now available

MINNEAPOLIS **Honeywell**

VALVE PRODUCTS

Another Mason-Neilan Basi

In 1944 — The C_v Concept — Universally Used Today

NOW! Point 4 Factor Trim

A thorough study of reduced capacity trim over the past decade has resulted in a new concept of the entire subject, leading to conclusions which are sound from both engineering and manufacturing standpoints and which simplify the problem for the user. Mason-Neilan now offers *Point 4 Factor Trim* based on the following general principles:

1. Since a properly designed wide range control valve will control satisfactorily near its stroke limits, a vast majority of flow problems can be handled by valves with full capacity trim. Therefore, unless the required reduction in capacity is appreciable, no advantage is obtained by the use of reduced capacity trim.

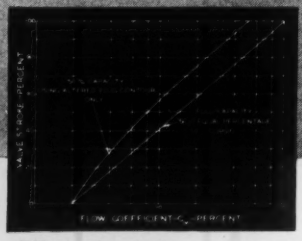
2. The only practical reduced capacity trim design is one which *extends the minimum* controllable flow as well as *reducing the maximum.* A simple analysis shows that to extend the minimum controllable flow it is *necessary to reduce the seat ring diameter.*

3. *Only one reduction* is practical for a given size top-and-bottom guided, double or single seated control valve. The optimum reduction consistent with retention of mechanical strength is approximately 60% of full capacity; hence the capacity of a valve with reduced capacity trim should be .4 of full capacity. The logical description of this trim is therefore —

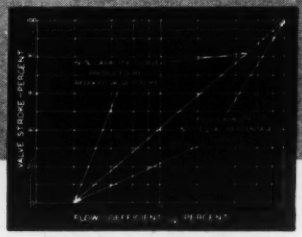
Point 4 Factor Trim

There are a number of valid reasons for specifying reduced capacity trim in control valves for industrial processes. Masoneilan *Point 4 Factor Trim* provides standardization, plus convenience in selection and procurement in handling these unusual applications.

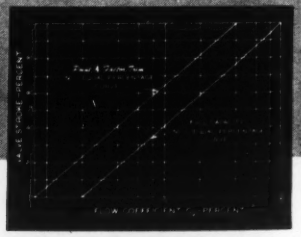
Complete details are available on request.



Effect of reducing *maximum* flow by altering plug contours only.



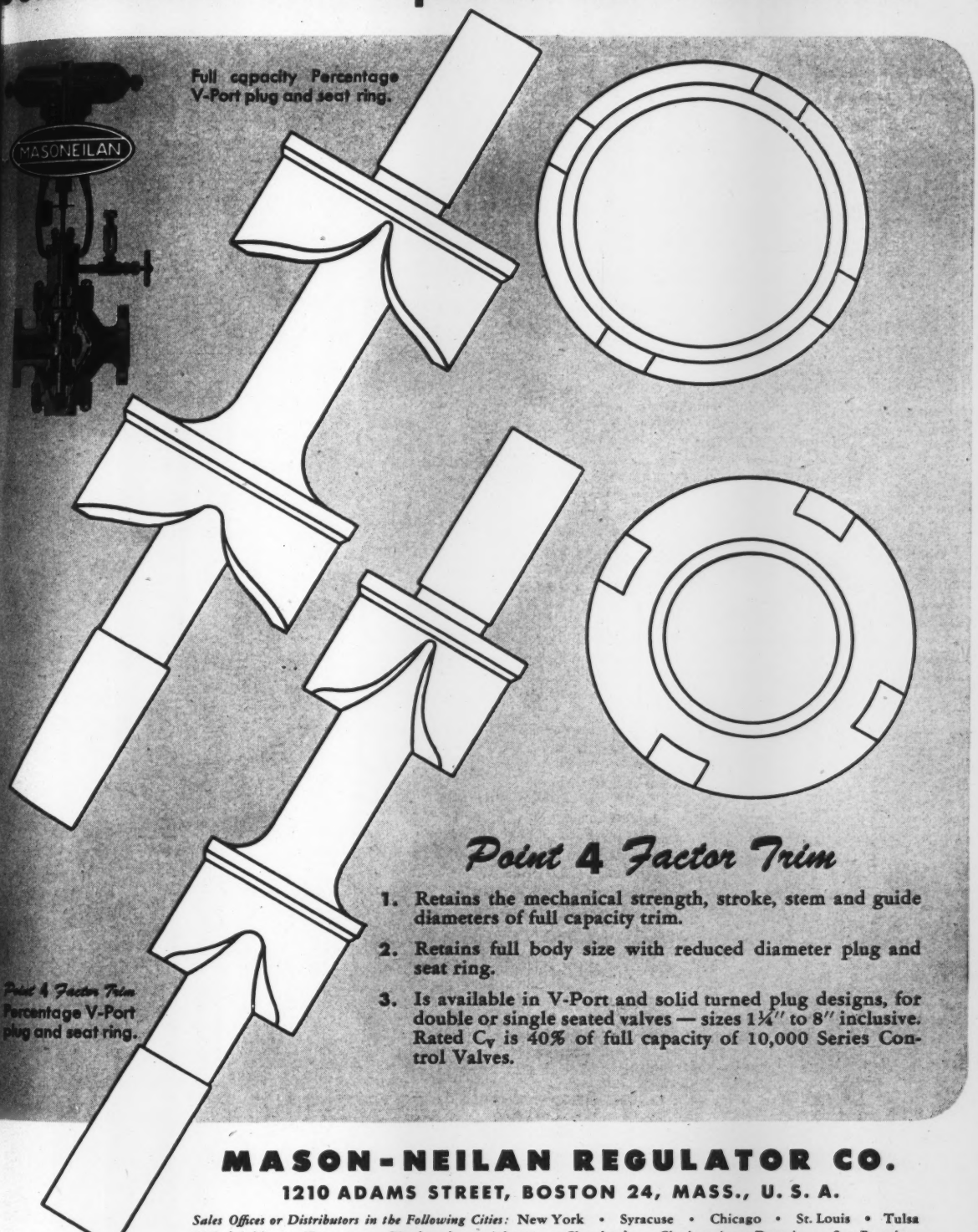
Note that same reduction of *maximum* flow can be obtained by reducing stroke by means of positioner adjustment or altered spring characteristic.



Effect of *Point 4 Factor Trim* obtained by using reduced plug and seat ring diameters.

Contribution to Simplified Valve Selection

Full capacity Percentage V-Port plug and seat ring.



Point 4 Factor Trim Percentage V-Port plug and seat ring.

Point 4 Factor Trim

1. Retains the mechanical strength, stroke, stem and guide diameters of full capacity trim.
2. Retains full body size with reduced diameter plug and seat ring.
3. Is available in V-Port and solid turned plug designs, for double or single seated valves — sizes 1¼″ to 8″ inclusive. Rated C_V is 40% of full capacity of 10,000 Series Control Valves.

MASON-NEILAN REGULATOR CO.

1210 ADAMS STREET, BOSTON 24, MASS., U. S. A.

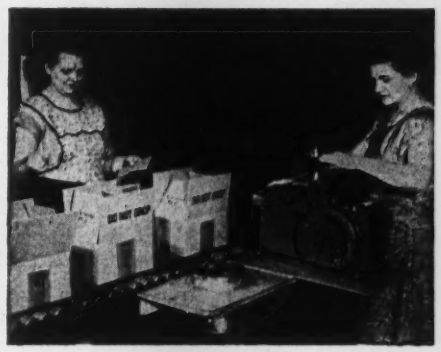
Sales Offices or Distributors in the Following Cities: New York • Syracuse • Chicago • St. Louis • Tulsa Philadelphia • Houston • Pittsburgh • Atlanta • Cleveland • Cincinnati • Detroit • San Francisco Salt Lake City • El Paso • Boise • Albuquerque • Charlotte, N. C. • Los Angeles • Denver Appleton, Wisconsin • Corpus Christi • New Orleans Mason-Neilan Regulator Co., Ltd., Montreal and Toronto

from Quality Production

AVAILABLE CAPACITY
FOR YOUR
DEFENSE NEEDS

n to Delivery on Schedule

Dependable



is the word for

For over 22 years Carboloy Company has led in *quality* and *uniformity* of man-made metals.

Carboloy Alnico Permanent Magnets are no exception. From the raw materials to finished permanent magnets, each undergoes the most rigid system of continuous quality control ever devised.

Quality checks and recordings, tests and retests are run to strict specifications by highly skilled personnel working with the latest equipment.

More, the same dependable control applies to *shipments*, too. Once Carboloy Company accepts and schedules your defense order, delivery is made as promised.

Result: Carboloy Alnico Permanent Magnets of the *highest uniform quality* roll into your plant on the dot.

For information on the availability of Alnico Permanent Magnets, write today. Carboloy's engineering consultants and technicians will give immediate attention to your magnet problems.

CARBOLOY COMPANY, INC.
A General Electric Affiliate
11155 E. 8 Mile Ave., Detroit 32, Michigan

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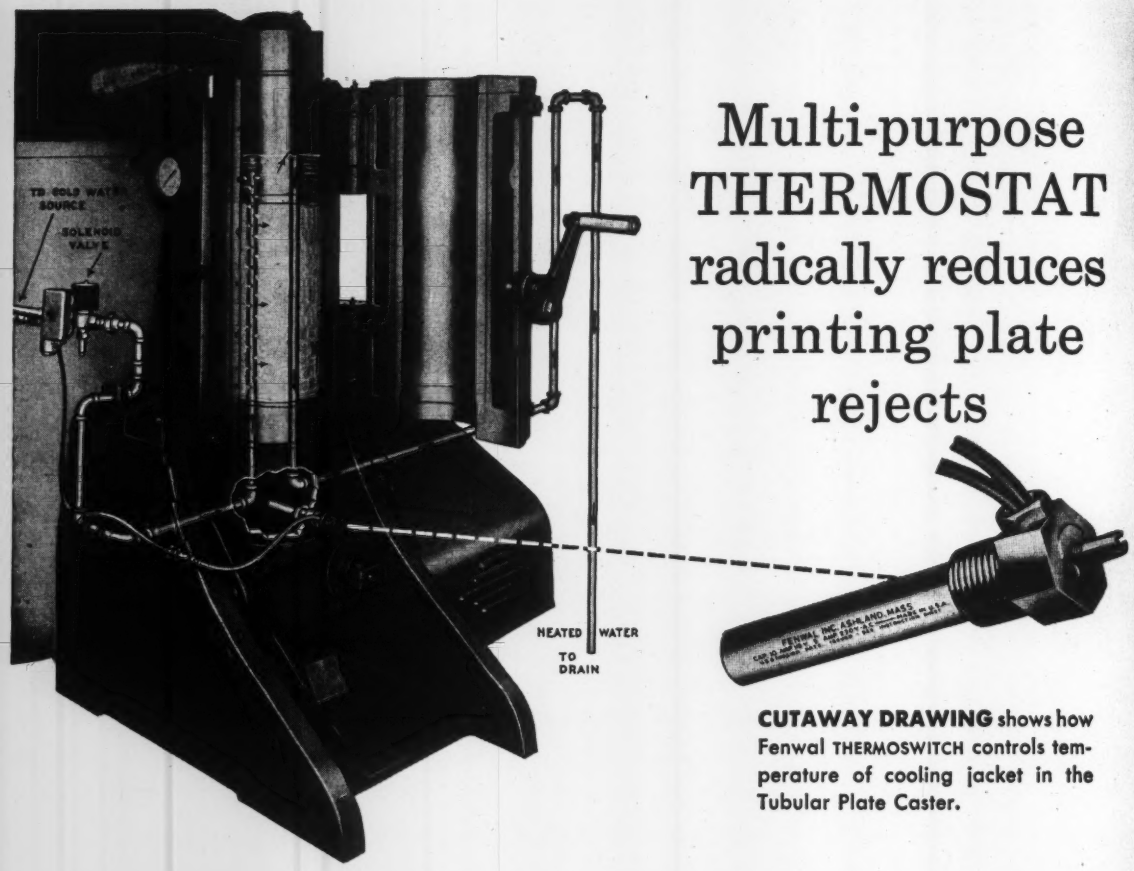
"Carboloy" is the trademark for the products of Carboloy Company, Inc.

ALNICO PERMANENT MAGNETS

Multi-purpose THERMOSTAT radically reduces printing plate rejects



CUTAWAY DRAWING shows how Fenwal THERMOSWITCH controls temperature of cooling jacket in the Tubular Plate Caster.

The Tubular Plate Caster machine used in the production of printing plates at the Nordmann Printing Company, 4210 Chippewa St., St. Louis was the seat of considerable trouble when it was water cooled by a hand valve. If too much cold water was run into the cooling jacket, the temperature was reduced so fast that the plates shrank. If too little water entered, the temperature remained too hot and plates became porous. In either case, plates had to be remelted and recast with resultant loss of labor and time.

The problem was solved by replacing the hand valve with a solenoid water valve and installing a low-cost Fenwal THERMOSWITCH thermostat. This unit opens the valve when water gets too hot. Cold water then flows in, hot water drains off, and valve is shut when proper water temperature is reached. *As a result, rejects have been practically eliminated.*

This is but one of many ways in which easy-to-install, easy-to-maintain Fenwal THERMOSWITCH Units effectively control variables where heat is a factor. Their unique principle of operation consists of an activating control element that is a single-metal shell. This shell expands or contracts *instantaneously* with temperature changes, making or breaking the totally enclosed electrical contacts.

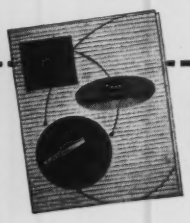
Fenwal THERMOSWITCH thermostats can no doubt help you in your own processing. Find out how by mailing the coupon today.

Fenwal

THERMOSWITCH

The Precision, Multi-Purpose, Thermostat Control

SENSITIVE . . . but only to heat



FREE! **Get this bulletin . . . see what Fenwal THERMOSWITCH units can do for you.**

Just fill in coupon and mail . . . no obligation.

FENWAL, INCORPORATED, 176 Pleasant St., Ashland, Mass.
111 South Burlington Ave., Los Angeles 4, Cal.

TEMPERATURE CONTROL ENGINEERS

Name ..... Position .....

Company .....

Street .....

City ..... Zone ..... State .....

I am chiefly interested in the applications checked:

- ☐ Heating
- ☐ Cooling
- ☐ Humidity Control or Detection
- ☐ Alarm (over-temperature, under-temperature)
- ☐ Vapor Control
- ☐ Timing (thermal)
- ☐ Radiant Heat Control
- ☐ Pressure Control (by controlling vapor temperature)

OTHER (Please fill in your special requirements) .....

.....

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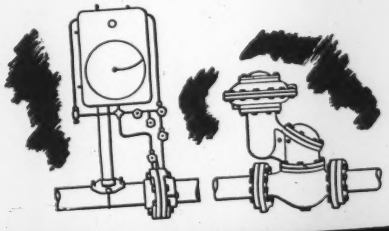
SOME EASTERN SEABOARD REGIONS NOW RECEIVING NATURAL GAS THROUGH AMERICAN METER COMPANY EQUIPMENT



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In the great new pipelines serving metropolitan Eastern United States, American Meter Company precision equipment plays a vital part. American instrumentation assures complete operating control, accurate records for better planning, reduction of operating costs and *satisfied* customers.

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INCORPORATED (ESTABLISHED 1836)

GENERAL OFFICES—60 EAST 42nd STREET
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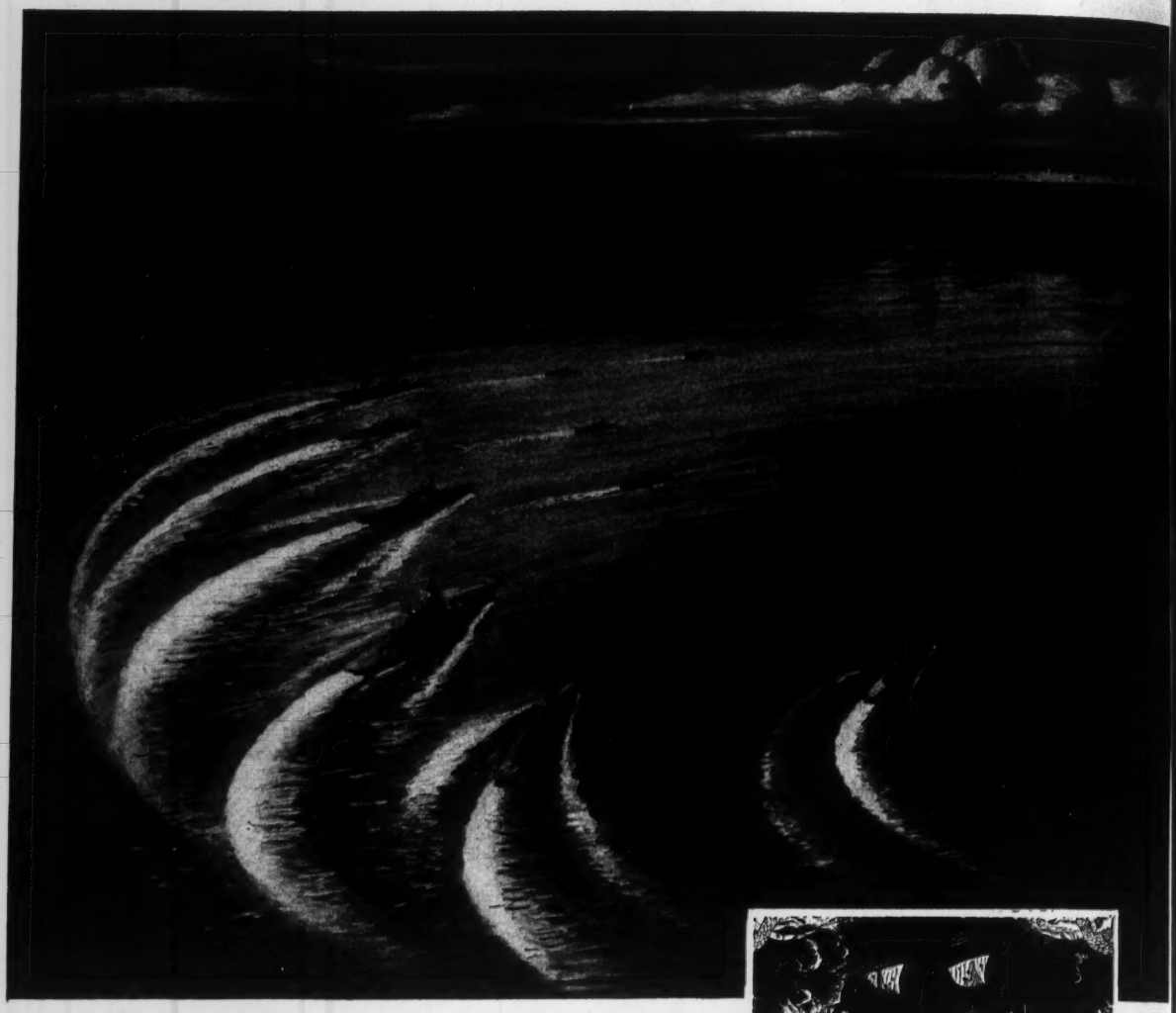
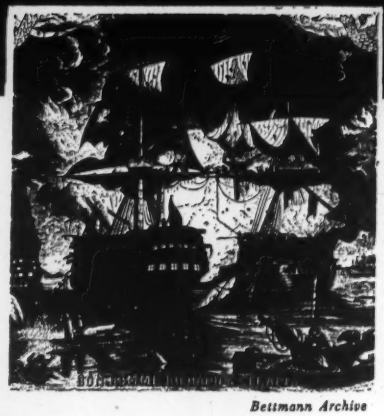
3. Orifice Meters Recording
4. Orifice Meters Integrating
5. Orifice Meters Telemetering
6. Orifice Meters Integrating Remote Counter
7. Meter Runs
8. Orifice Fittings
9. Differential Valves
10. Controllers, Pressure
11. Controllers, Flow
12. Temperature and Pressure Recorders





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"ON TARGET" TODAY

demands split-second mathematics

Today's gunnery problems are a far cry from the days of slugging it out at close range. They demand instantaneous solutions to ever-increasing complex factors. Only continuing advance in electronic instrumentation can accomplish this feat. Through years of outstanding engineering design and precision manufacture, Arma leads in this vital supply link to our *nation's Armed Forces.*

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ARMA CORPORATION

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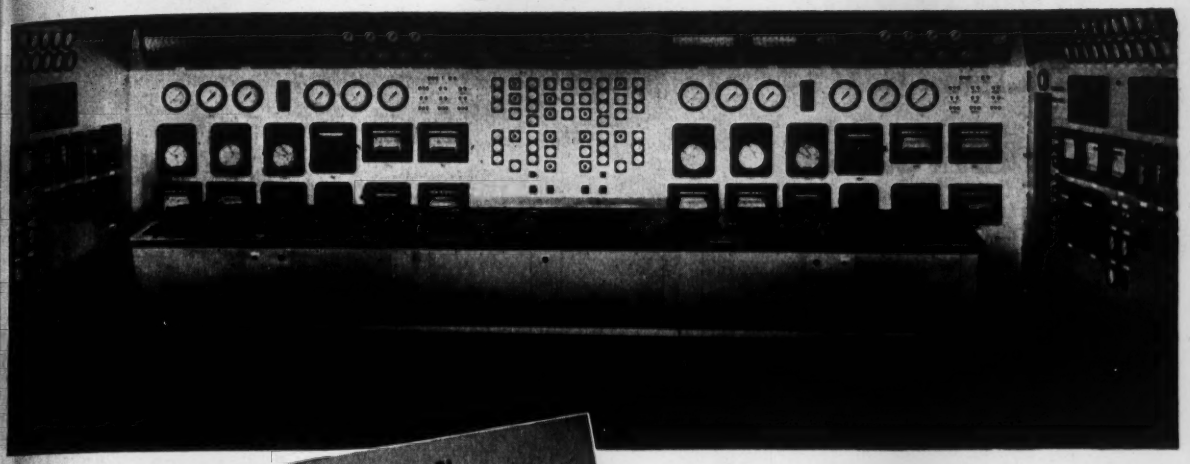
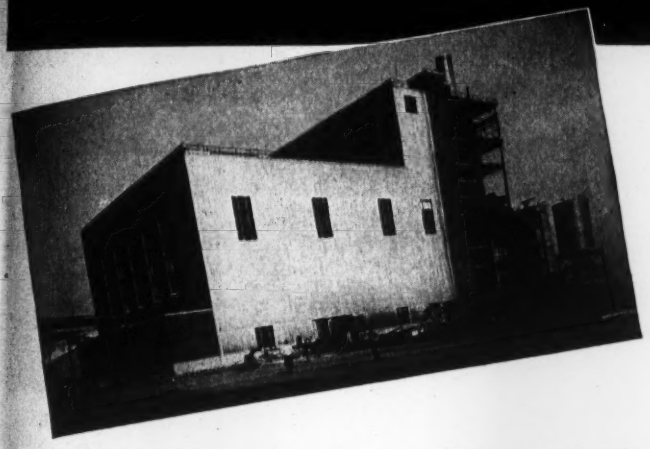
SUBSIDIARY OF AMERICAN BOSCH CORPORATION

DURAGAUGE *specified . . .*





. . . *another major installation of* ASHCROFT DURAGAUGES

Shown above is the central control room of the new Edge Moor Power Station of the Delaware Power and Light Company now under construction by United Engineers & Constructors, Inc.

Recognized as "the standard of the industry," the Ashcroft Duragauge has an unmatched record of performance in the most severe installations to be found in the power field.

The Duragauge, as engineers will verify wherever it is installed, combines the most modern concepts of design and manufacture with experience that goes back over a century.

THE NYLON MOVEMENT is exclusive with the Duragauge. It provides unprecedented impact absorption, retention of form and shape under high temperatures, low friction, and corrosion resistance.

BOURDON TUBE MATERIALS for every service. These include phosphor bronze, beryllium copper, Monel, alloy steels, and stainless steels 316, 431, and 347.

CASE DESIGNS for any purpose in phenol condensate, "alumalife," iron, and brass. Stem, flush or wall mounting.

ROTARY MOVEMENT DESIGN enables recalibration in the field with maximum accuracy in minimum time.

See your local distributor for the gauge that means lowest maintenance costs—the Ashcroft Duragauge. He invites your inquiries.

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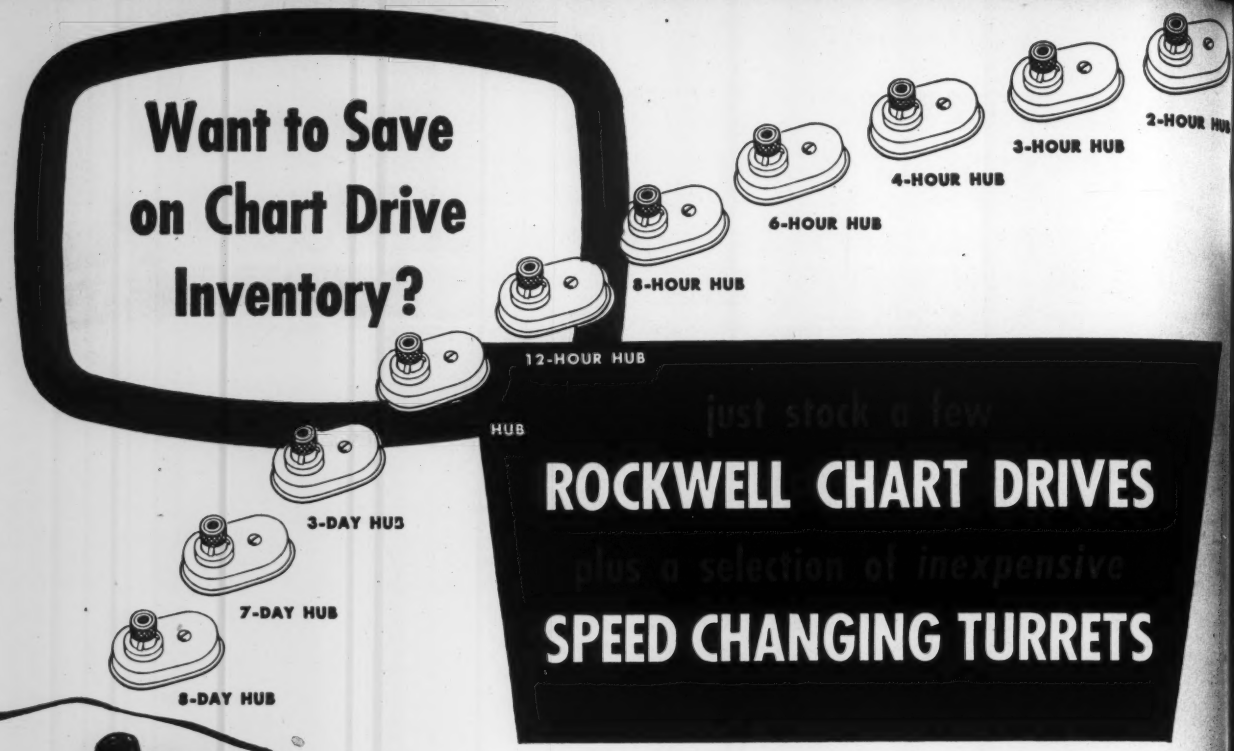
Makers of 'Ashcroft' Gauges, 'Hancock' Valves, 'Consolidated' Safety and Relief Valves, 'American' Industrial and 'Microsen' Electrical Instruments. Builders of 'Shaw-Box' Cranes, 'Budgit' and 'Load Lifter' Hoists and other lifting specialties.

Want to Save on Chart Drive Inventory?



just stock a few

ROCKWELL CHART DRIVES

plus a selection of *inexpensive*

SPEED CHANGING TURRETS

Illustrating how the Turrets lock onto the chart arbor to change rotation speeds. This conversion feature is also available on the 8-day Rockwell midget drive.

For replacement service, the Rockwell standard chart drive is the most versatile, economical you can use. It is thinner than other drives and so can be correctly located in practically any instrument case by means of simple adaptors. One adaptor is furnished with each drive. Rotation speeds are no problem, either. Speed changing Turrets lock onto the chart arbor to provide any one of 11 rotation speeds. Think what this means in reduced inventory, service work, all-around flexibility of application.

Get facts now on long-lived, powerful, Rockwell chart drives. Learn how their use in your instrument shop will save time and money. Write for bulletin.

There are two basic models of the Rockwell standard drive—24 hour rotation, 8 day wind; 7 day rotation, 31 day wind. Turret speed changers provide a wide selection of alternate rotation speeds.

Write for Bulletin 1079

ROCKWELL MANUFACTURING COMPANY

PITTSBURGH 8, PA.

Atlanta · Boston · Chicago · Columbus
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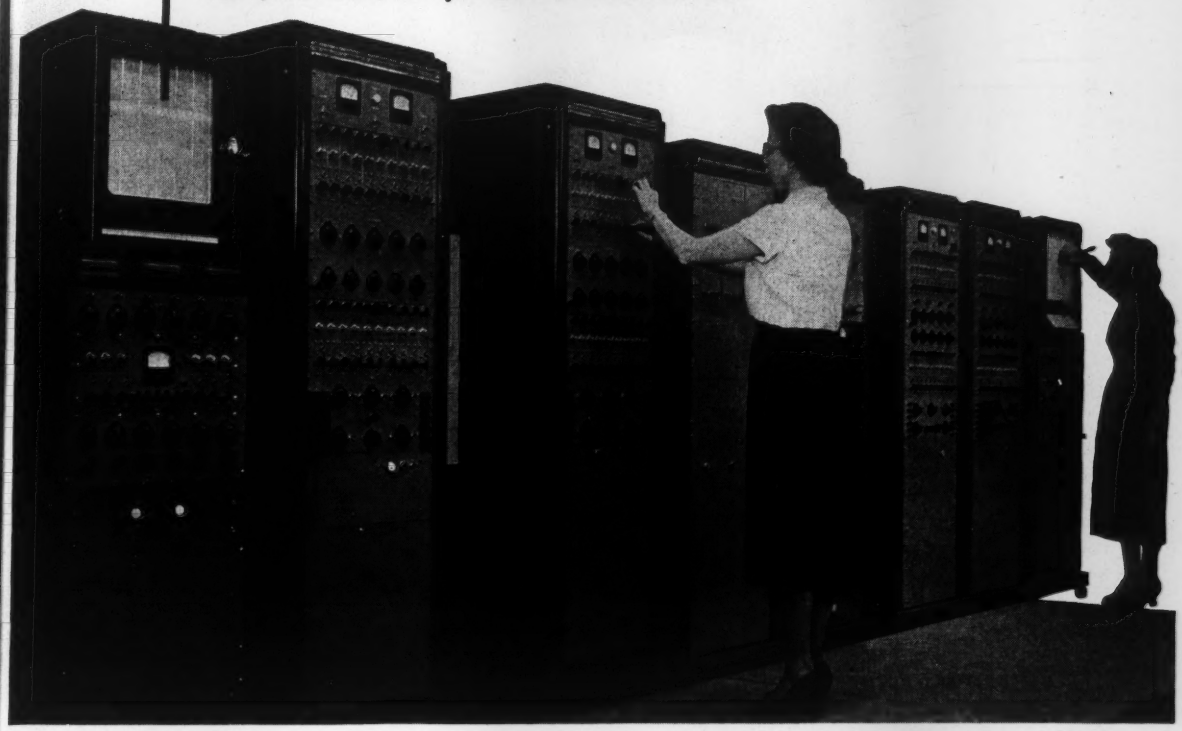
You have your choice of two models in the Rockwell Midget. (1) A 24 hour drive with 24 hour rotation only, and a 48 hour rundown. (2) An 8 day drive with basic 24 hour rotation that can be converted with Turrets to 10 alternate speeds ranging from 2 hour to

Look into this *MIGHTY MIDGET*

Compact, powerful drives for use in instruments when space is at a premium. They feature a detachable escapement, sealed in clear plastic. They wind through the chart arbor, snap into separate mounting rings which may be positioned on bosses or adaptors to fit

Brush recorder



...memory for an electronic brain

● Goodyear Aircraft's Electronic Differential Analyzer provides a method of studying performance of dynamic systems without computations by a corps of mathematicians.

Since there is a direct analogy between the dynamic behavior of electrical and mechanical systems, the performance of one system can be predicted by a study of the other. Thus, by setting up the proper electrical circuits, problems in such varied fields as aircraft design and control, vibration analysis, industrial control, structures, turbines and engines, and other dynamic systems can be solved with the Differential Analyzer.

The memory for this electronic "brain" is provided by a Brush Recording Analyzer. Here, results from as many as six different computations are recorded simultaneously. Permanent visual records are made instantaneously, eliminating laborious plotting.

Investigate Brush instruments for studies of d-c or a-c voltages or currents, strains, displacements, light intensities, temperatures, and other static or dynamic conditions. Write for information. The Brush Development Company, Dept. A-9, 3405 Perkins Avenue, Cleveland 14, Ohio, U. S. A. *Canadian Representatives:* A. C. Wickman (Canada) Limited, P. O. Box 9, Station N, Toronto 14, Ontario.

Heart of each Brush Recorder is the Brush Magnetic Penmotor—a high-speed, direct-writing element for instantaneous, permanent recording. Flat frequency response and linear phase shift with frequency permit accurate reproduction of both transient phenomena and steady state signals.

Put it in writing with a

BRUSH RECORDING ANALYZER

THE **Brush** DEVELOPMENT COMPANY

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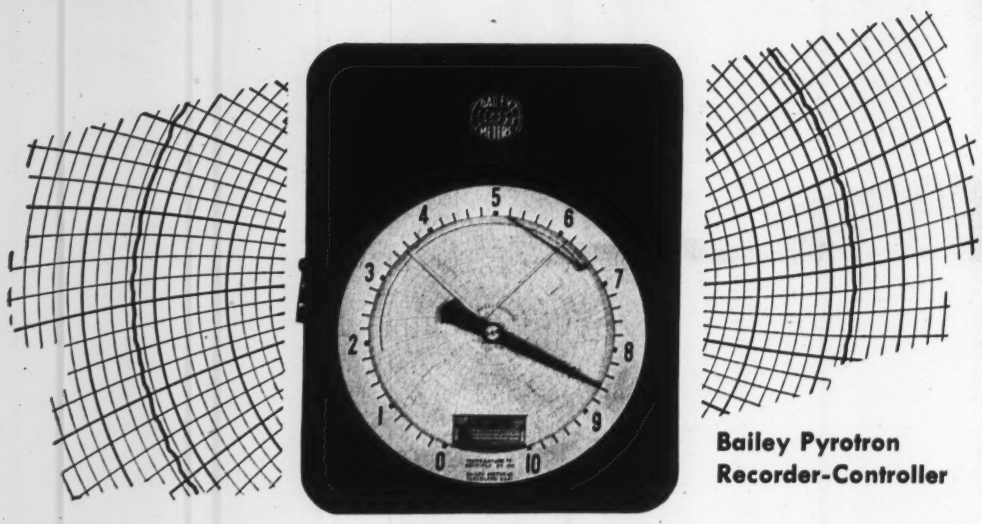


Bailey Pyrotron
Recorder-Controller

Looking for Better Temperature Instruments?

. . . Then check these features of Pyrotron Electronic Resistance Thermometers . . .

FUNDAMENTAL ACCURACY

Bailey Pyrotron Resistance Elements are made of highest purity platinum—the material used by the National Bureau of Standards in establishing basic standards for temperatures from −190°C to +660°C.

THREE TYPES OF CONTROL

Pyrotron Controllers may operate: on-off electrical systems by either electronic relays or electric contacts, modulated electronic systems, or air-operated systems. Two temperatures may be recorded on the same chart and controlled by a single instrument.

FACTS PUT INTO USABLE FORM

Bailey Pyrotrons may be arranged to put temperature facts into convenient usable forms. If two or more temperatures are related, they may be recorded as continuous records on the same chart for easy comparison. The average of several temperatures or the difference between two temperatures may be recorded as a single continuous record which may be retransmitted to a distant point or used to actuate a control system.

EASY INSTALLATION

Bailey Pyrotrons do not require careful leveling or protection against vibration. Three ordinary copper wires are all that is needed to connect each temperature sensitive element with the recorder. Power may be taken from any 115 volt 60 cycle circuit.

MINIMUM MAINTENANCE

The absence of galvanometers, batteries and standardizing equipment, together with the use of interchangeable unit assemblies, reduces Pyrotron maintenance to the vanishing point.

ABUNDANT POWER

A separate motor drive for each temperature furnishes abundant power to operate a recording pen, a controller and an alarm switch.

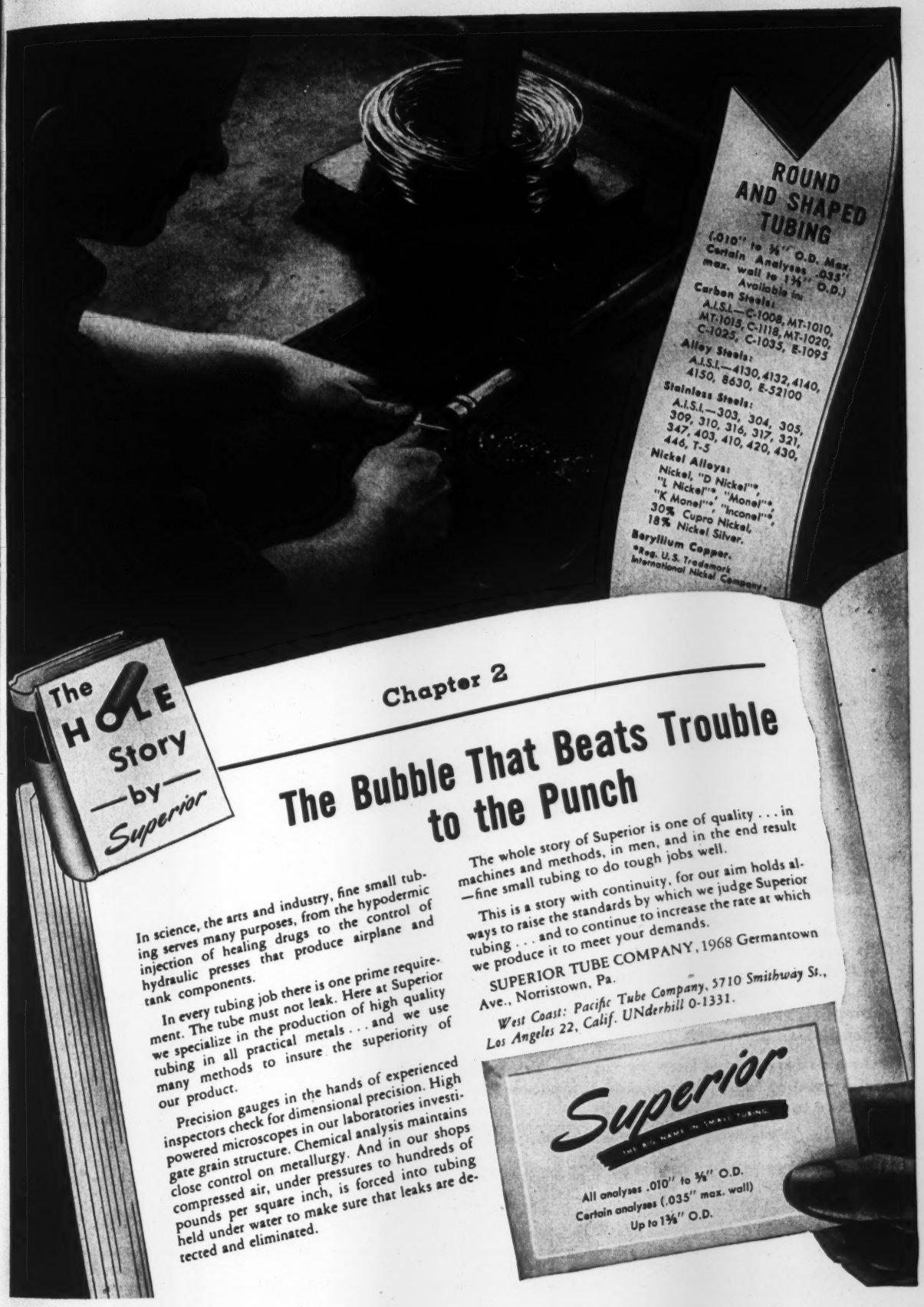
For the full story on this unusual electronic resistance thermometer which is suitable for ranges between —300°F and 1200°F, ask for Bulletin No. 230-C. P-21

BAILEY METER COMPANY

1041 IVANHOE ROAD • • • CLEVELAND 10, OHIO

Controls for Processing

TEMPERATURE
PRESSURE
% OXYGEN
% COMBUSTION
FLOW
LEVEL
DENSITY
RATIO


ROUND AND SHAPED TUBING
(.010" to ¾" O.D. Max. Certain Analyses .033" max. wall to 1¾" O.D.) Available in:
Carbon Steels:
A.I.S.I.—C-1008, MT-1010, MT-1015, C-1118, MT-1020, C-1025, C-1035, E-1095
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Nickel Alloys:
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Beryllium Copper.
*Reg. U.S. Trademark International Nickel Company.
The HOLE Story —by— Superior
Chapter 2
The Bubble That Beats Trouble to the Punch
In science, the arts and industry, fine small tubing serves many purposes, from the hypodermic injection of healing drugs to the control of hydraulic presses that produce airplane and tank components.
In every tubing job there is one prime requirement. The tube must not leak. Here at Superior we specialize in the production of high quality tubing in all practical metals . . . and we use many methods to insure the superiority of our product.
Precision gauges in the hands of experienced inspectors check for dimensional precision. High powered microscopes in our laboratories investigate grain structure. Chemical analysis maintains close control on metallurgy. And in our shops compressed air, under pressures to hundreds of pounds per square inch, is forced into tubing held under water to make sure that leaks are detected and eliminated.
The whole story of Superior is one of quality . . . in machines and methods, in men, and in the end result —fine small tubing to do tough jobs well.
This is a story with continuity, for our aim holds always to raise the standards by which we judge Superior tubing . . . and to continue to increase the rate at which we produce it to meet your demands.
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West Coast: Pacific Tube Company, 5710 Smithway St., Los Angeles 22, Calif. UNderhill 0-1331.
Superior
THE BIG NAME IN SMALL TUBING
All analyses .010" to ⅜" O.D.
Certain analyses (.035" max. wall)
Up to 1⅜" O.D.

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V-RING PACKING CONVERSION KIT

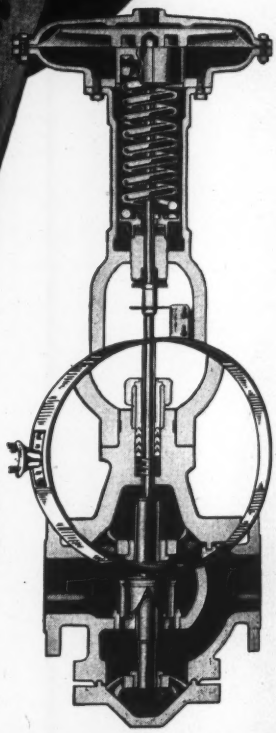
A *Complete*

PACKAGED UNIT

This complete packaged Fisher Teflon V-Ring Conversion Kit converts a standard Fisher stuffing box unit to Fisher Teflon V-Ring Packing. It offers prompt service, guarantees a true fit and insures damage-free delivery.

When ordering, be sure to furnish the valve serial number found stamped on the patent plate attached to yoke or body.

* Teflon is the trade name of E. I. DuPont de Nemours & Co.



Fisher Teflon V-Ring Packing is furnished as standard on new Fisher Diaphragm Motor Valves.

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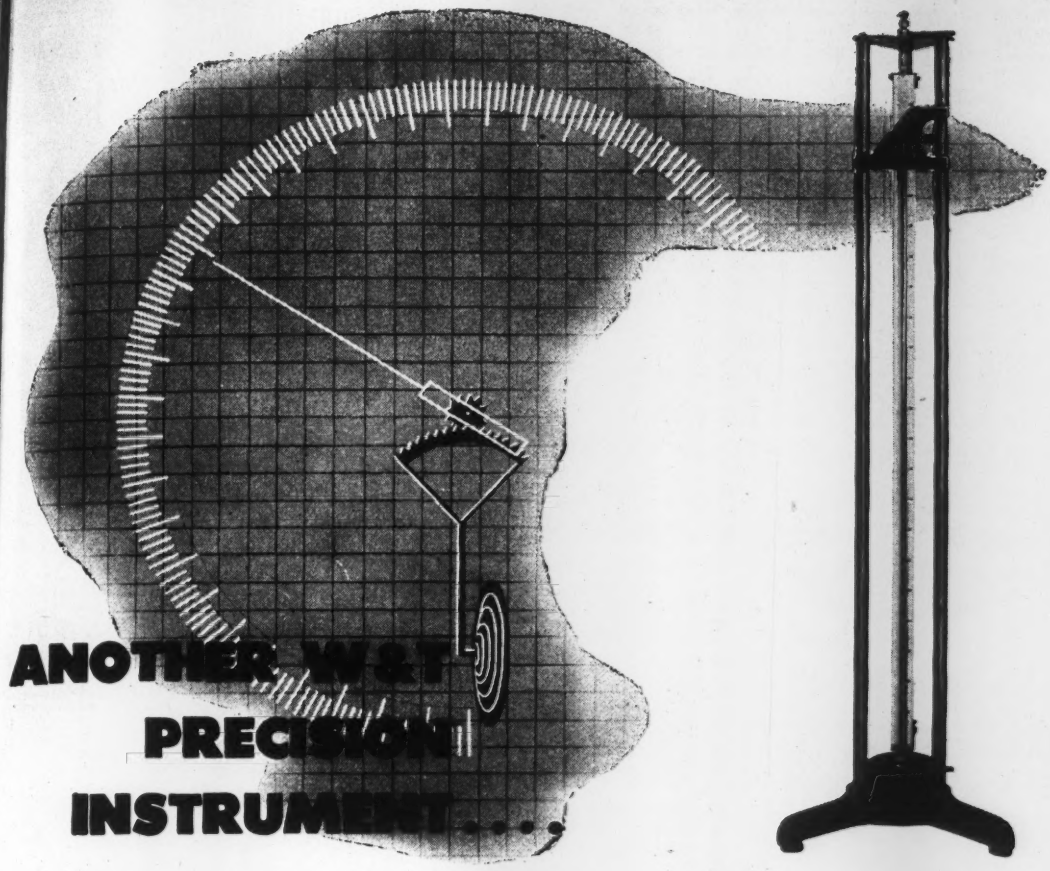
FISHER

WORLD LEADER IN THE MANUFACTURE OF PRESSURE REGULATORS AND IN RESEARCH FOR BETTER PRESSURE CONTROL



The W & T Precision Mercurial Manometer

The W&T Precision Mercurial Manometer couples maximum precision with ease in handling. These two features have made it a leading instrument in modern research and manufacture for such uses as measuring sample pressures in infrared spectroscopy and calibrating aircraft altimeters. Because of its flexibility and accuracy, the Manometer can be used for almost any type of pressure measuring problem in the range of two atmospheres.

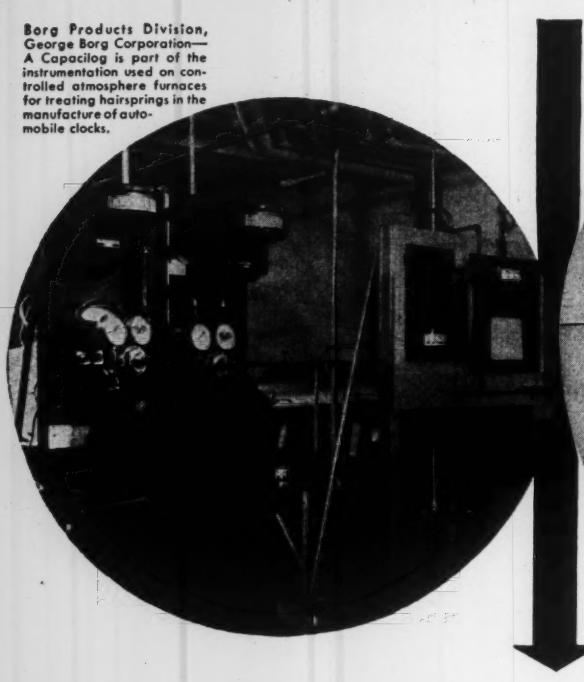
Such characteristics are only part of the picture. Take a look at these additional features:

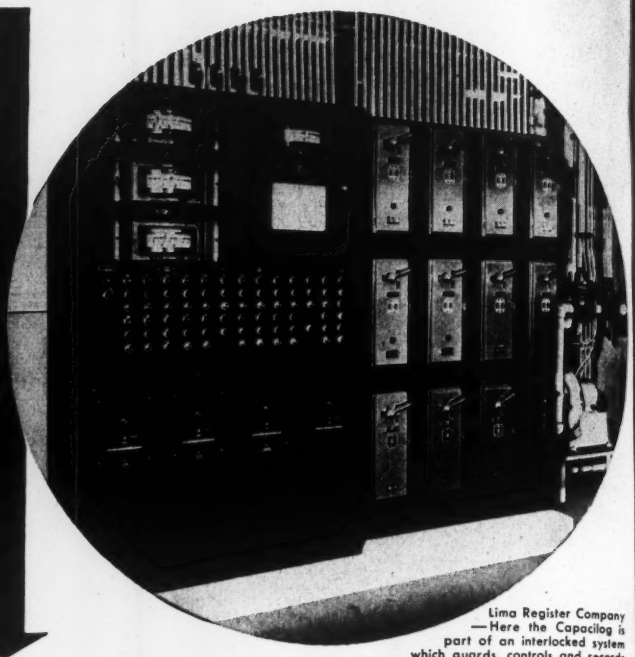
1. Float type indicator eliminates difficulty in reading meniscus.
2. Adjusting knob provides for temperature compensation over a range of 30° C.
3. Precision bore manometer tube provides accuracy with interchangeability.
4. Fixed cistern type manometer requires only one reading.
5. Mercury sealed valve permits evacuating the tube simply and easily at the point of use.
6. Flexible design permits measurement of absolute pressure, gauge pressure, differential pressure, and vacuum.

For more details, write today for free technical bulletin TP-29-A.

WALLACE & TIERNAN
PRODUCTS, INC.
ELECTRICAL MECHANISMS AND PRECISION INSTRUMENTS
Belleville 9, New Jersey • Represented in Principal Cities

Borg Products Division, George Borg Corporation—A Capacilog is part of the instrumentation used on controlled atmosphere furnaces for treating hairsprings in the manufacture of automobile clocks.





Lima Register Company—Here the Capacilog is part of an interlocked system which guards, controls and records the operation of a four compartment high pressure spray type washing machine, dry-off oven, automatic electrostatic spray booths and bake oven.

instrumentality in action . . . for versatility!

Yes, it's the Wheelco Capacilog—versatile enough to be used in laboratories, ceramic production, heat treating, plastic manufacturing, chemical processing, oil refining—wherever the highly accurate measurement, control and permanent record of process variables is needed—at one or more checking points.

Whether the Capacilog is used for the measurement, control and permanent record of temperature, speed, static strain loads, AC-DC voltage, amperage or other electrically measurable factors, it proves itself a simple, versatile instrument which does a complex job accurately, efficiently and economically.

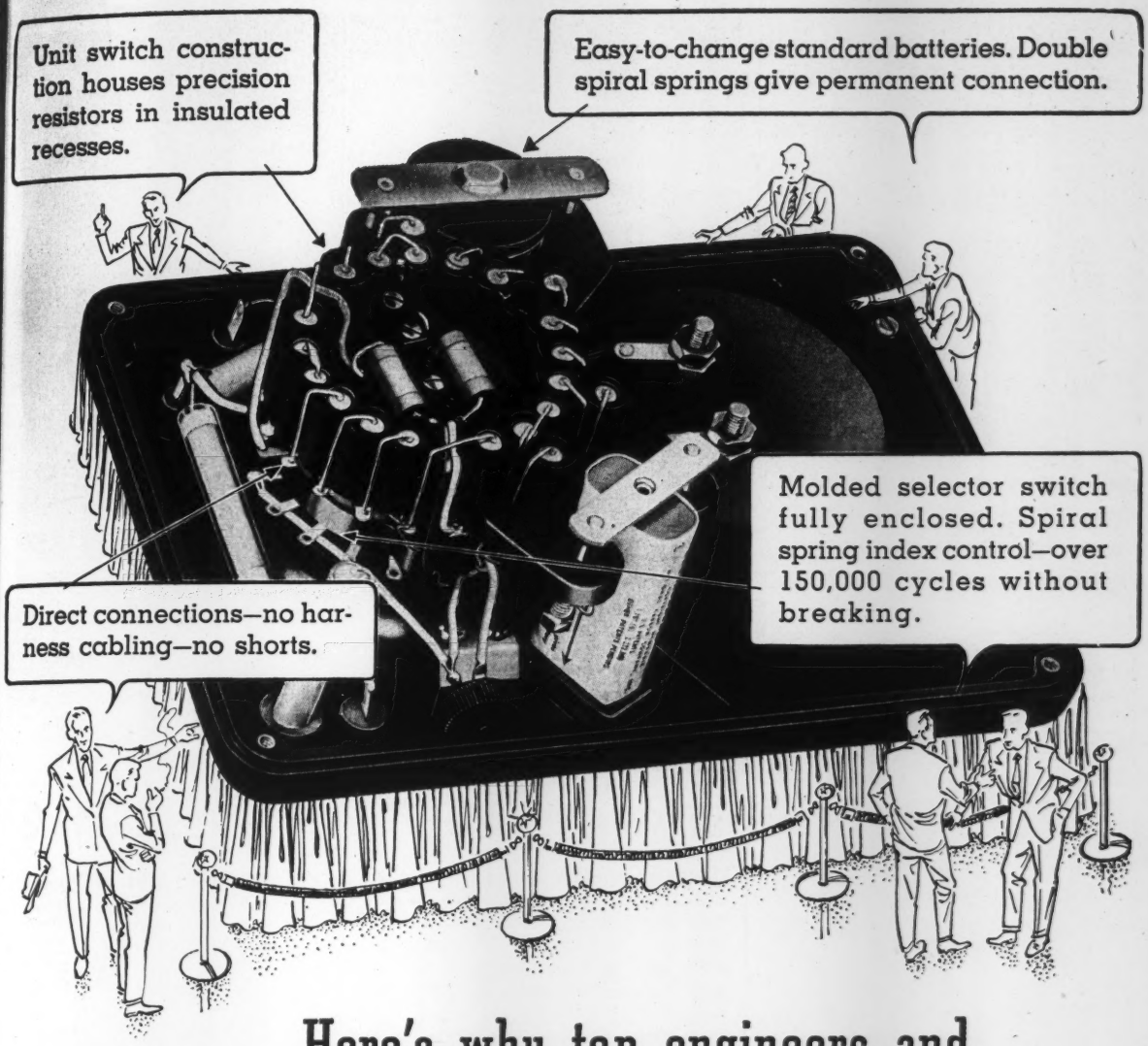
That's why every day more and more of the nation's leading plants are specifying the Wheelco Capacilog and getting the plus benefits of Wheelco *Instrumentality*, the sensible, simplified, low-cost answer to your need for a versatile, accurate instrument with a wide range of applications.

Follow the leaders . . . specify the Wheelco Capacilog—despite present day shortages the Capacilog is available on a reasonable delivery basis.

Investigate the Capacilog line of strip chart recorders today—write for Bulletin C2 for complete details. See how Capacilog versatility makes it adaptable to a variety of applications.

Wheelco Instruments Company, 833 West Harrison Street, Chicago 7, Illinois

wheelco *electronic controls*


Unit switch construction houses precision resistors in insulated recesses.
Easy-to-change standard batteries. Double spiral springs give permanent connection.
Molded selector switch fully enclosed. Spiral spring index control—over 150,000 cycles without breaking.
Direct connections—no harness cabling—no shorts.

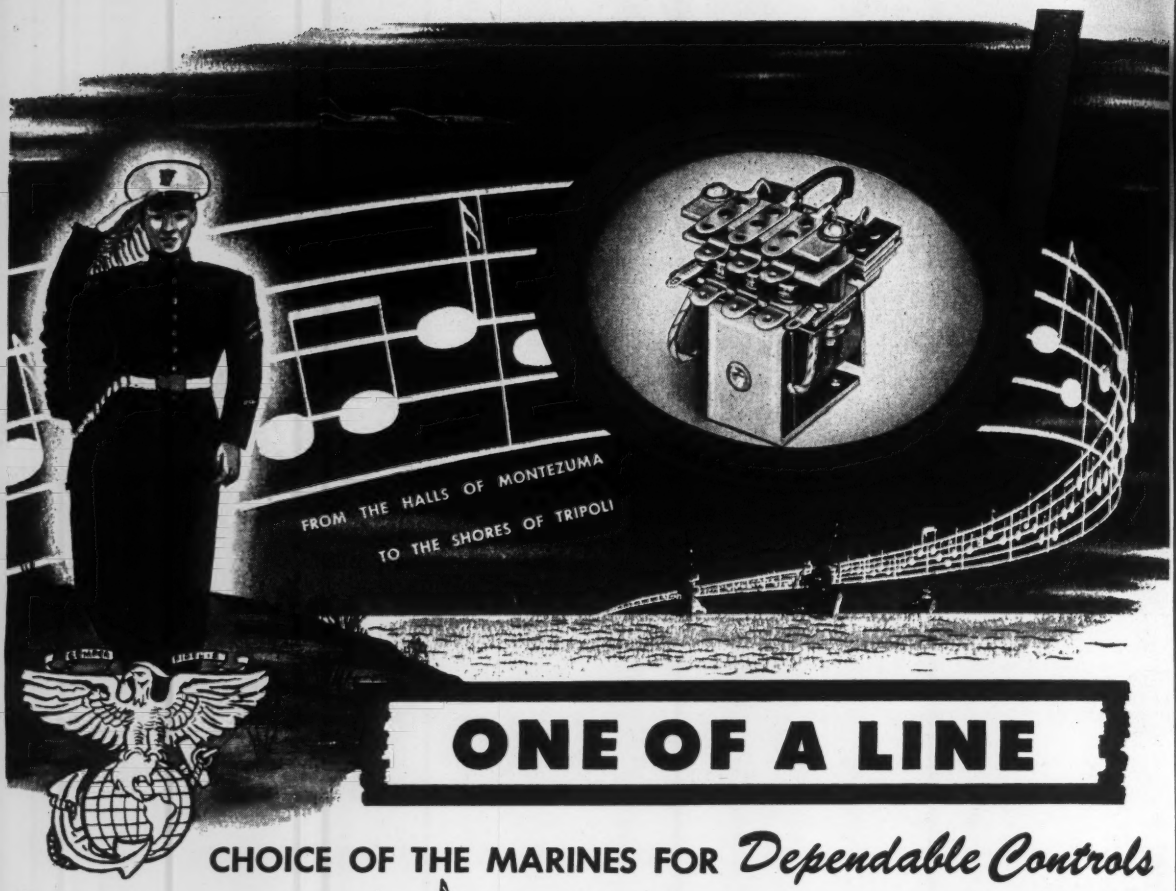
Here's why top engineers and technicians use Model 630

Features like those shown above are what make this popular V.O.M. so outstandingly dependable in the field. The enclosed switch, for instance, keeps the silvered contacts *permanently clean.* That's rugged construction that means stronger performance, longer life. And tests show that the spiral spring index control, after more than 150,000 cycles of switch rotation, has no disruption or appreciable wear! Investigate this history-making Volt-Ohm-Mil-Ammeter today: 33 ranges, large 5½" meter.

FOR THE MAN WHO TAKES PRIDE IN HIS WORK

Triplett

TRIPLETT ELECTRICAL INSTRUMENT COMPANY · BLUFFTON, OHIO, U.S.A.



ONE OF A LINE

CHOICE OF THE MARINES FOR *Dependable Controls*

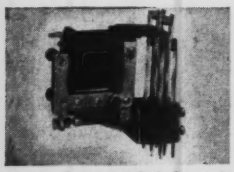
GUARDIAN RELAYS

"From the halls of Montezuma" to marine testing laboratories — technicians are singing the praise of Guardian Relays. The Series 335 D.C. Relay shown above is but one of a most comprehensive line of Guardian Relays *approved* by the Marine Corps and all branches of the Armed Forces. Available with open-type construction or *hermetically sealed* — Guardian's Series 335 D.C. Relay or any Government Approved Guardian control unit used singly, in combination, or in completely packaged controls, will serve you faithfully and well.

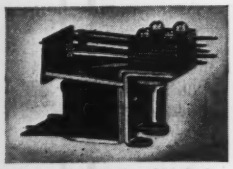
The Series 335 D.C. Guardian Relay shown above is available with the A.N. Connector Plug, Octal Plug and Lug Header hermetic seal *containers. Packs loads of power over a wide operating range, withstands the rigors of dust, moisture, salt air, temperature changes, vibration and impact.*

A.N. CONNECTOR PLUG HERMETIC SEALED CONTAINER

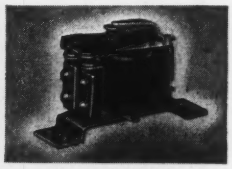
NEW CATALOG on Hermetically Sealed Guardian Relays with various containers is yours for the asking, cost-free.



Series 30 A.C.



Series 210 A.C.—215 D.C.



Series 220 A.C.

Series 595 D.C.

Series 610 A.C.—615 D.C.

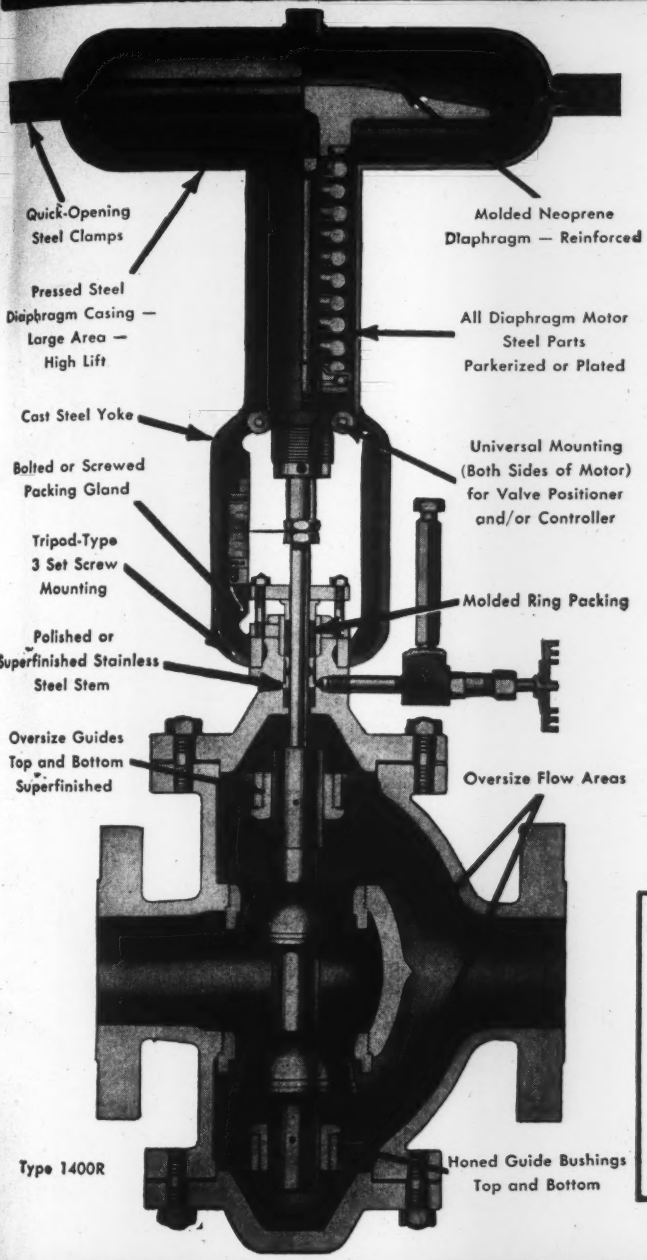
WRITE OR WIRE... FREE CATALOG, SPECIFIC RECOMMENDATIONS, NO OBLIGATION.

GUARDIAN ELECTRIC

1638-G W. WALNUT STREET CHICAGO 12, ILLINOIS

A COMPLETE LINE OF RELAYS SERVING AMERICAN INDUSTRY

ADVANCED-TYPE VALVE FOR EXACTING CONTROL


Quick-Opening Steel Clamps
Molded Neoprene Diaphragm — Reinforced
Pressed Steel Diaphragm Casing — Large Area — High Lift
All Diaphragm Motor Steel Parts Parkerized or Plated
Cast Steel Yoke
Universal Mounting (Both Sides of Motor) for Valve Positioner and/or Controller
Bolted or Screwed Packing Gland
Tripod-Type 3 Set Screw Mounting
Molded Ring Packing
Polished or Superfinished Stainless Steel Stem
Oversize Guides Top and Bottom Superfinished
Oversize Flow Areas
Type 1400R
Honed Guide Bushings Top and Bottom

K & M Diaphragm Control Valves embody the accessibility and other desirable features of the "open yoke", formerly available only in cast iron construction, together with the strength and resistance to shock found only in steel.

The diaphragm casing assembly is the exclusive K & M Boltless Duoseal design which allows quick disassembly. The large diaphragm is molded so there is full effective contact with the diaphragm button during the complete valve stroke. This construction, together with heavy, calibrated, long-travel springs gives an unusually high power factor for extremely precise control.

Flow passages of the valve body have a minimum average area of 140% of comparable size pipe area; inner valve open free areas average 80% of pipe area. This design permits pressure drop to take place principally through the inner valve, assuring complete control over the full valve stroke.

Send for K & M Bulletin S10 for details and data.

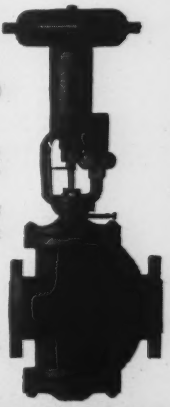
K&M SERIES 1200 and 1400

Available sizes — ½ to 16 inches.

Construction — Cast iron, carbon and stainless steels and most machineable alloys.

Inner Valves — A wide range of styles and characteristics to meet varying requirements.

Action — Designed for direct or reverse action.



KIELEY & MUELLER

Established 1879

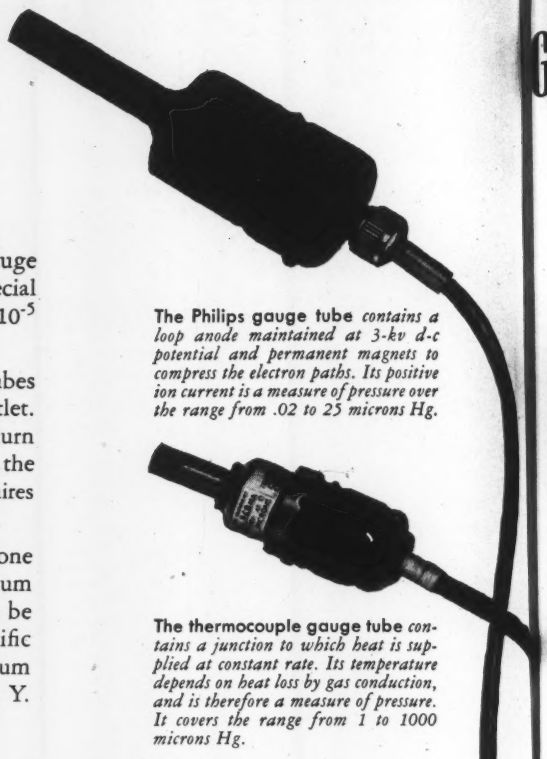
2033 - 43rd STREET NORTH BERGEN, N J.

even a surge to full atmosphere can't hurt this team..

DPi has combined the thermocouple gauge and the Philips gauge into a single instrument that's low in price, requires no special operating precautions, and covers the entire range from 2×10^{-5} mm. to 1 mm. Hg on a single meter.

The combination circuit uses three readily available radio tubes and three selenium rectifiers. It operates from any 115-v a-c outlet. No panel adjustments are necessary. All the operator does is turn it on and read the pressure. It can be calibrated, if needed, from the outside of the 10″ x 8″ x 8″ cabinet. It's easily portable and requires no precautions against any pressure surges, even up to atmosphere.

The new Combination Thermocouple and Philips Gauge is one more step in DPi's continuing program to make high vacuum simple and inexpensive to create, measure, and use. We'll be glad to discuss your requirements in detail and quote specific prices. Simply write to: ***Distillation Products Industries,*** Vacuum Equipment Department, 765 Ridge Road West, Rochester 3, N. Y. (Division of Eastman Kodak Company).

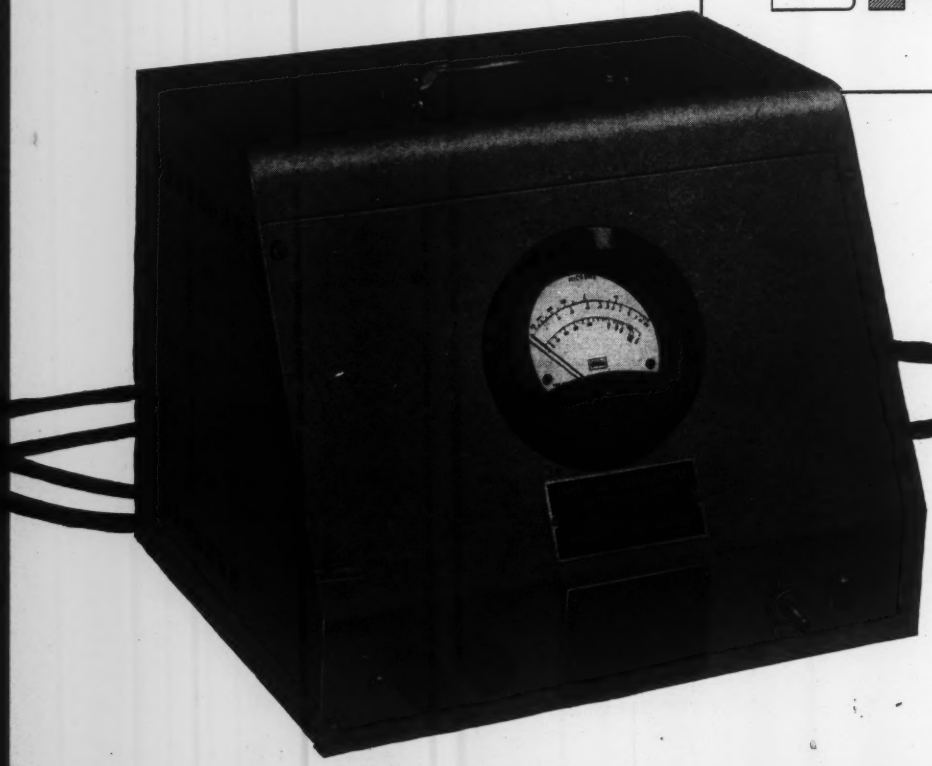


The Philips gauge tube *contains a loop anode maintained at 3-kv d-c potential and permanent magnets to compress the electron paths. Its positive ion current is a measure of pressure over the range from .02 to 25 microns Hg.*

The thermocouple gauge tube *contains a junction to which heat is supplied at constant rate. Its temperature depends on heat loss by gas conduction, and is therefore a measure of pressure. It covers the range from 1 to 1000 microns Hg.*

high vacuum research and engineering

DPi



Also... vitamins A and E... distilled monoglycerides... more than 3400 Eastman Organic Chemicals for science and industry

GOTHAM CONVERTIBLE

grows or changes to fit your needs

Want an instrument that can grow or change to fit your needs—an instrument that is a miser for maintenance and replacement inventory?—Then choose the Gotham Convertible. It is a 1-2-3-4 pen recorder; 14 pressure, temperature and time operation combinations. It is a recorder controller; there are 38 pressure, temperature and time operation combinations.

All components are Gotham standard, factory calibrated systems, completely interchangeable and easily removable or replaceable at the job site.

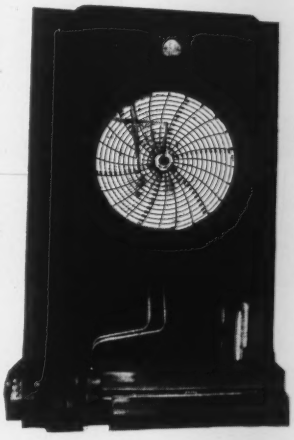
Number of functions possible depends on whether instrument is 6", 9" or 12" chart size.

GOTHAM INSTRUMENTS

Keep everything under control with Gotham

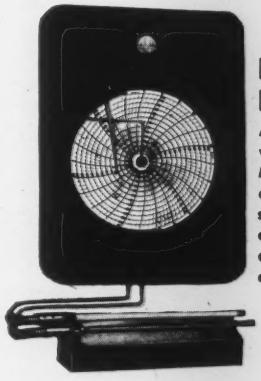
SELF-CONTAINED PORTABLE RECORDER

Here, at last, is a portable recorder built to full-size instrument reliability. Built from Gotham standard elements, interchangeable with other Gotham instruments. 6", 9" and 12" chart sizes. Mercury, Vapor or Pressure Actuated. Spring or electric chart drive. See Catalog 400.



RECORDING PSYCHROMETER

Incorporates highly accurate and responsive thermal systems and many other Gotham standard convertible elements. Wet and dry bulb type. Motor-driven suction fan. 12" chart size. Catalog 400.



RECORDING HYGROMETER

A 2-pen recorder of the wet and dry bulb type. Mercury or Vapor Actuated. 9" and 12" chart sizes. Available with variety of wet and dry bulb assemblies depending on application. Catalog 400.

GOTHAM INSTRUMENTS
Division of American Machine and Metals, Inc.
Dept. 2, 233 Broadway
New York 12, New York

Please send me a copy of your

- ☐ Catalog 100—Industrial Thermometers
- ☐ Catalog 200—Dial Type Thermometers
- ☐ Catalog 400—Recorders, Psychrometers, Hygrometers
- ☐ Catalog 500—Controllers
- ☐ Have your representative call. No obligation.

Name.....Title.....

Company.....

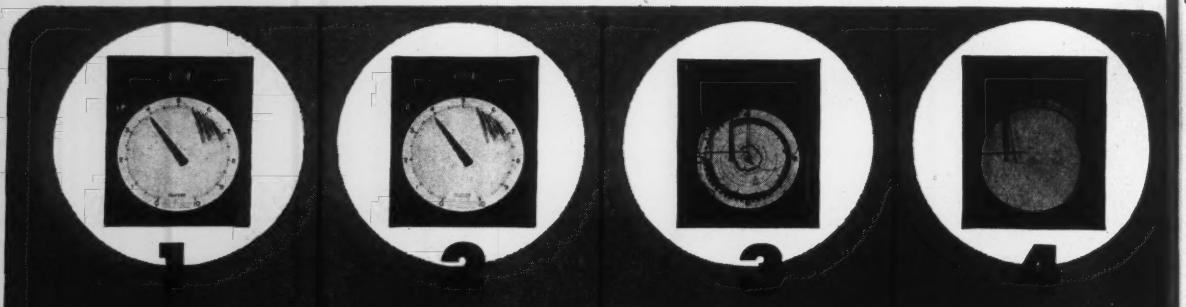
Address.....

City.....Zone.....State.....

4 ways to know your combustion efficiency

The ever-increasing pressure for fuel economy makes some type of "combustion guide" instrument an essential part of any modern fuel burning operation. Hays offers the most complete line of such instruments in the industry—adaptable to your cost and engineering requirements. Your particular needs with regard to price, accuracy, speed of response, etc., will determine your choice—*however, whatever your needs, Hays has the instrument.*

Select your combustion guides *from the most complete line in the industry*



Measures fundamental indicator of combustion efficiency —Oxygen. Electronic in operation, with all of the most advanced features incorporated into its design, it is applicable not only to power plant conditions but also to a host of process problems such as catalytic crackers, open hearths, process heaters, inert gases, etc.

PRINCIPLE

Based on paramagnetic (attracted by magnetism) properties of oxygen. All other gases usually encountered are slightly diamagnetic (repelled by magnetism).

FEATURES

Highly sensitive to change in O_2 content
Rapid response to change in O_2 content
Electrically operated
Electronic type recorder
Temperature controlled
Pressure compensated
No liquid or gaseous fuel required to be added
No chemicals
High accuracy maintained
Not affected by wide change of gas flow rate
Continuous sampling and recording
Glass and corrosive resistant sampling system
Remote mounted analyzer
Remote mounted recorder
12" 24-hour chart
O_2 recorder and indicator
4 records on same chart possible
Low maintenance

Meter incorporates all of the construction and manufacturing ideas which Hays has developed during many years of experience in gas analysis. A deluxe instrument, the Condu-Therm CO_2 Analyzer is especially applicable to the larger boiler plants and to industrial processes.

PRINCIPLE

The principle of operation used in the Hays Condu-Therm Meter is that of thermal conductivity of gases, i.e., that all gases conduct heat at different rates.

FEATURES

Electrically operated
Electronic type recorder
Temperature controlled
Humidity controlled
No chemicals required
No moving parts in analyzer
Continuous sampling
No drying agent required
Easily installed glass and corrosion resisting sampling system
Not affected by wide change in gas flow rate
Rapid response
High sensitivity
Continuous recording
Remote mounted analyzer
Remote mounted recorder
12" 24-hour chart
CO_2 Recorder and Indicator
As many as 4 records on same chart
Low maintenance

Hundreds of these meters have been in operation for many years in all types of plants burning all kinds of fuels and saving thousands of fuel dollars.

PRINCIPLE

Operates on Orsat principle of Volumetric measurement and chemical absorption. Extremely simple: sample of flue gas trapped and accurately measured; passed through chemical which removes CO_2 component of gas mixture. Sample is re-measured, volume compared to original sample. Difference before and after absorption gives exact percentage of CO_2 absorbed by chemical.

FEATURES

Low price
Water operation
Pressure and temp. compensated
Volumetric determination
Chemical absorption
2 minute operating cycle
Easily understood
Rugged construction
Low maintenance
Available in 6 remote mounted types and 3 integral types
Remote or integral mounting
10" 24-hour chart
Available for: (a) CO_2 only—recording with or without indicator (b) CO_2 and flue gas temperature recorder combined (c) CO_2, draft or flue gas temperature recorder combined

Provides a QUANTITATIVE guide to efficiency — deals with quantities of air and steam; by contrast CO_2 and O_2 meters are QUALITATIVE guides since they determine directly quality of combustion gases. Both Boiler Efficiency Meter and Gas Analysis Meter are used to obtain advantages of both methods.

PRINCIPLE

Pounds of air required to burn each pound of coal vary widely with heating value of coal; constant weight of air is required to produce same Btu. Similar relationship exists when oil and natural gas are used as fuels. Record of steam flow is assumed to be Btu's produced; record of air flow is calibrated to flow of air required to generate that steam.

FEATURES

Electric operation of flow meter and air flow recorder
Diaphragm type air flow measuring unit
Air flow measuring element does no work
Air flow recorder—motor operated
Adjustable cam air flow calibration
Mercury transmitter—pressures to 2500 psi
Interchangeable range tubes for steam flow
Remote mounted steam flow transmitter
No high pressure piping into panel
Easily installed and adjusted
Low maintenance

THE HAYS CORPORATION
Michigan City 8, Indiana

Automatic Combustion Control • Boiler Panels • Hays-Penn Flowmeters Veriflow Meters and Veritrol • Gas Analyzers • Draft Gages Combustion Test Sets • CO_2 Recorders • Electronic Oxygen Recorders

WHAT PRICE PERFECTION!

"PERFECTION" is the most important word in the entire English language to a group of men at John Chatillon & Sons.

These researchers, engineers and planners are constantly working toward the improvement of measuring apparatus that already connotes perfection to every user

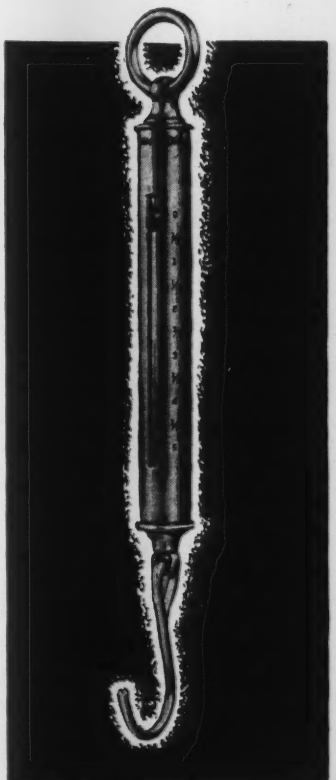
For example: These Force Measuring Devices, which are the finest available, are individually calibrated and guaranteed to be accurate within one graduation mark on the gauge. This exactness is universally accepted, inasmuch as such devices simply are not expected to be more accurate. But — to John Chatillon & Sons, it represents a challenge—and full time research is constantly going on, until "Perfection"—complete and ultimate, is achieved.

"Resting on Laurels" is an invalid phrase at Chatillon.

CHATILLON SPECIAL FORCE MEASURING DEVICES

Only one fine Chatillon Device from Our Complete Line

- For adjusting Spring Tension of D.C. Motor Brush Holder
- For use with Torque Measuring Devices
- For Measuring Force in All Phases of Industrial & Laboratory Work



JOHN CHATILLON & SONS

will design and manufacture Scales and other Measuring Devices to Meet Your Particular Needs.

FILL IN AND MAIL COUPON TODAY

John Chatillon & Sons, 85 Cliff Street, New York 7, N. Y.

Gentlemen: Please send me brochures and price information on

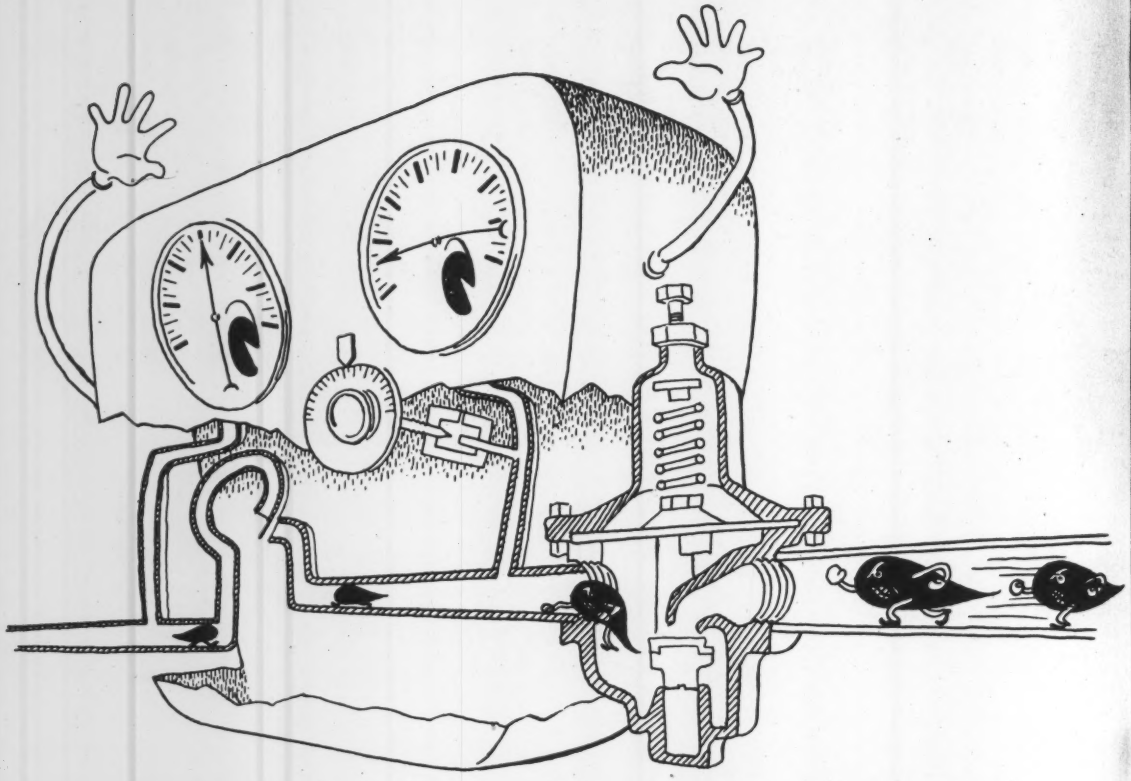
☐ Force Measuring Devices ☐ Traction Dynamometers
☐ Push Pull Gauges ☐ Laboratory Scales

Name..... Company.....

Address..... Position Held.....

JOHN CHATILLON & SONS 85 Cliff Street, Dept. I-5 New York 7, N. Y.

Manufacturers and Designers of Precision Instruments Since 1835

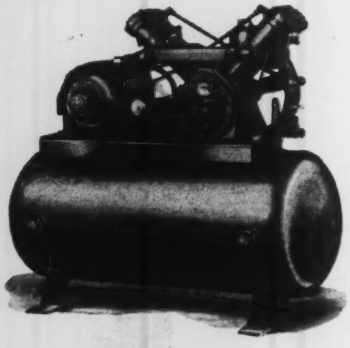


Picture of a tragedy about to happen!

It doesn't take much imagination to realize what's going to happen when those slugs of oil hit Mr. Instrument! You know how oil in compressed air instrument lines can foul-up production, cause down-time, and play havoc with maintenance costs. And the real tragedy is that oil in instrument lines just *isn't* necessary these days.

Here's why: Ingersoll-Rand has trouble-free air compressors that *don't pump oil.* NL Compressors feature pistons fitted with patented, graphitic-carbon rings. The rings prevent metallic contact of the piston with the cylinder bore. These carbon rings are segmental with metallic inner expanding rings to give the proper wall pressure. Because of the elimination of metallic contact, and the self-lubricating qualities of the carbon rings, the Ingersoll-Rand NL Compressor cylinders require no lubricant.

Here's your opportunity to cure a lot of maintenance and production headaches caused by oil slugs in instrument lines. Ingersoll-Rand has complete engineering data on NL Compressors that will interest you . . . including the 2 or 3 hp Model 235 HNL shown below plus other models available through 250 hp. Contact your nearest I-R representative, or write direct to Ingersoll-Rand Company, 11 Broadway, New York 4, New York.

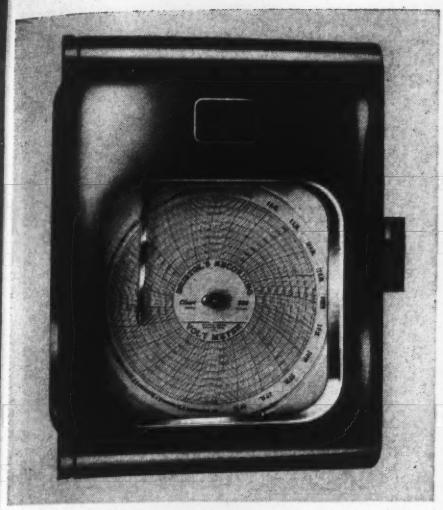


Ingersoll-Rand

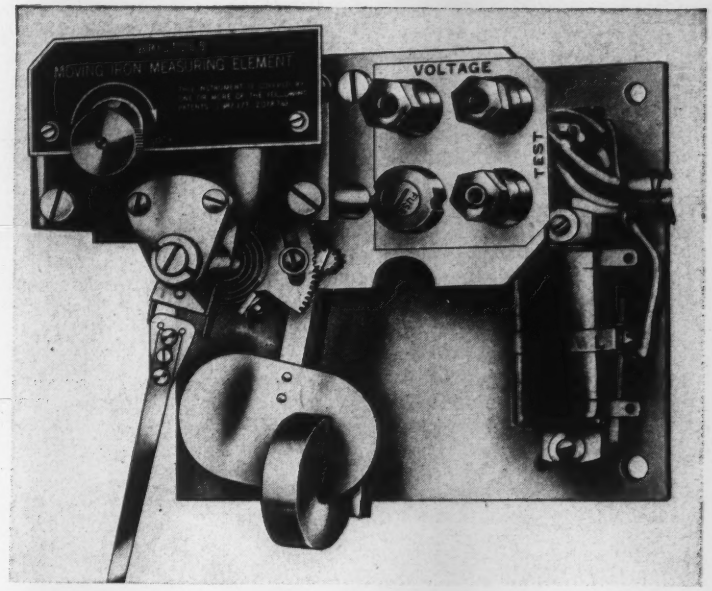
NL COMPRESSORS

. . . 70 years of compressor "know-how" packed into these **new compressors** for air operated instruments!

627-3



PERMANENT MOUNTING offered in three models: interchangeable surface and flush, surface-panel and flush panel. Note the pleasing, well-balanced appearance. Also: **PORTABLE INSTRUMENTS** are offered in two models: for setting on floor or table; for mounting on walls or poles and general service.



NEW MOVING-IRON MEASURING MECHANISM. High torque. low burden, rugged construction for assurance that the original calibration will be retained through years of service. Shock-absorbing stainless steel bearings.

NEW RECORDING VOLTMETERS AND AMMETERS ANNOUNCED BY BRISTOL

THE LATEST DEVELOPMENT IN ELECTRICAL MEASUREMENT

Outstanding for—High actuating torque... Low electrical burden... Stability of calibration... Dependable accuracy

Here is electrical measurement at its finest . . . most dependable . . . most convenient to use—the product of nearly 60 years of experience in building recording voltmeters and ammeters for almost every application.

The new moving-iron measuring mechanism is a type known for high actuating torque and low electrical burden . . . refined by Bristol engineers for greater accuracy and ruggedness.

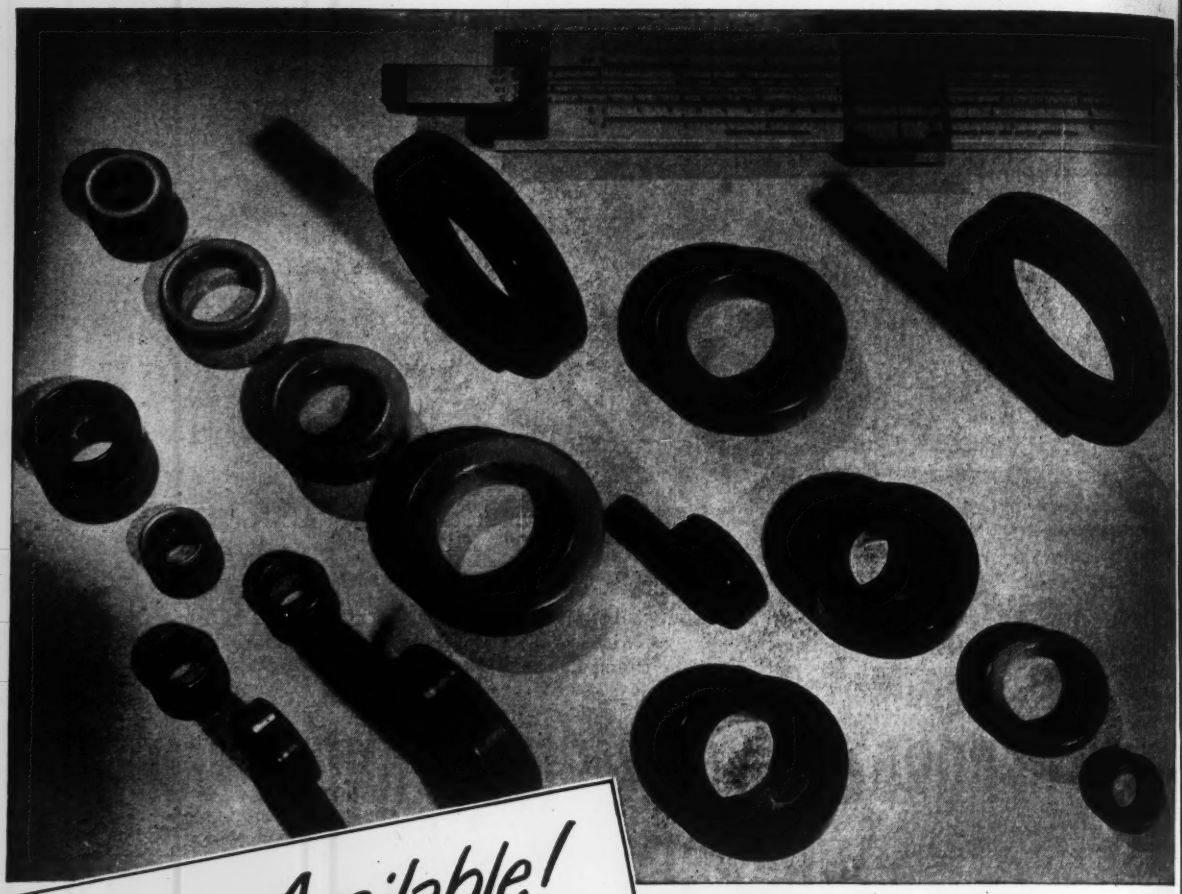
Other Bristol developments that assure convenience in use include the new Series 500 dust- and moisture-protected die-cast aluminum case, quick-set chart hub for easy chart changing, non-obscuring pen lifter, snap-on chart plate.

To keep up with the latest in recording instruments, send for Bulletin E1111, addressing THE BRISTOL COMPANY, 113 Bristol Road, Waterbury 20, Conn.

THE DEPENDABLE GUIDEPOST OF INDUSTRY

BRISTOL

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS



Now Available!

MOLYBDENUM PERMALLOY POWDER CORES*

HIGH Q TOROIDS for use in Loading Coils, Filters, Broadband Carrier Systems and Networks—for frequencies up to 200 KC

COMPLETE LINE OF CORES TO MEET YOUR NEEDS

- ★ **Furnished in four standard permeabilities—125, 60, 26 and 14.**
- ★ **Available in a wide range of sizes to obtain nominal inductances as high as 281 mh/1000 turns.**
- ★ **These toroidal cores are given various types of enamel and varnish finishes, some of which permit winding with heavy Formex insulated wire without supplementary insulation over the core.**

For high Q in a small volume, characterized by low eddy current and hysteresis losses, ARNOLD Moly Permalloy Powder Toroidal Cores are commercially available to meet high standards of physical and electrical requirements. They provide constant permeability over a wide range of flux density. The 125 Mu cores are recommended for use up to 15 kc, 60 Mu at 10 to 50 kc, 26 Mu at 30 to 75 kc, and 14 Mu at 50 to 200 kc. Many of these cores may be furnished stabilized to provide constant permeability (±0.1%) over a specific temperature range.

** Manufactured under licensing arrangements with Western Electric Company.*

W&D 2930

THE ARNOLD ENGINEERING COMPANY

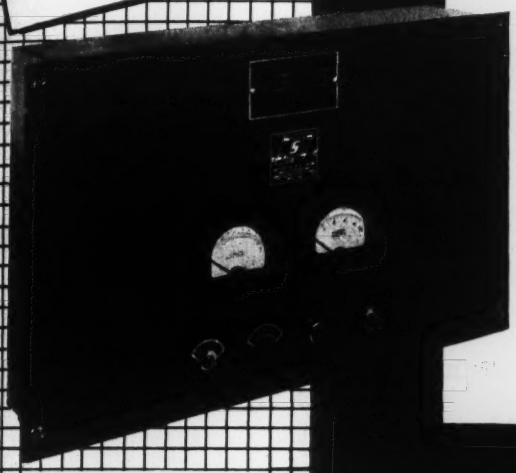
SUBSIDIARY OF ALLEGHENY LUDLUM STEEL CORPORATION

General Office & Plant: Marengo, Illinois

specify Sorensen

NOBATRONS

(DC VOLTAGE REGULATORS)



MODEL NO. E-6-15

DO YOU WANT the *advantages* of storage battery characteristics without the *disadvantages?* Then equip with Sorensen NOBATRONS! You get adjustable output voltage, stabilized against changing line AND LOAD conditions. You eliminate battery charging and maintenance, gas, acid hazard.

Like all Sorensen regulators, the NOBATRON is a painstakingly engineered combination of fine workmanship and top-quality components. That means accurate, trouble-free operation; long life!

STANDARD MODELS

6-VOLT SERIES

E-6-5	E-6-40
E-6-15	E-6-100

12-VOLT SERIES

E-12-5	E-12-30
E-12-15	E-12-50

28-VOLT SERIES

E-28-5	E-28-70
E-28-10	E-28-150
E-28-30	E-28-350

48-VOLT SERIES

E-48-15

125-VOLT SERIES

E-125-5	E-125-10

Model numbers indicate voltage and current; for example, E-6-5 indicates 6 VDC with 5 amp total capacity.

COMMON ELECTRICAL SPECIFICATIONS

Input voltage range	95-130 VAC; adapter transformers available for 230 VAC operation*
Output voltage range	Adjustable ± 10%
Regulation accuracy and load range	± 0.2% from 1/10 load to full load
Ripple voltage RMS max.	1%
Recovery time	0.2 second—this value includes charging time of filter circuit for the most severe change in load or input conditions
Input frequency range	50-60 cycles

*Some high current units require three-phase input

Write for Complete Literature

For other regulation problems investigate Sorensen's line of AC Voltage Regulators, Voltage Reference Standards, DC Power Supplys.

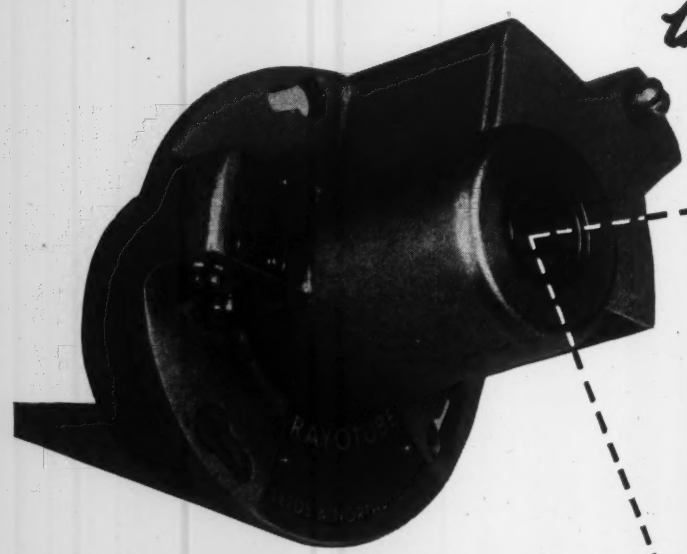
controlled POWER converted

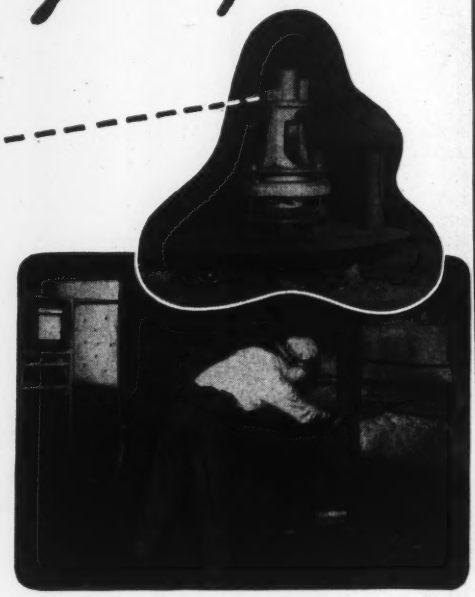
Sorensen and company, inc.

375 FAIRFIELD AVE. • STAMFORD, CONN.

MANUFACTURERS OF AC LINE REGULATORS, 60 AND 400 CYCLES; REGULATED DC POWER SOURCES; ELECTRONIC INVERTERS; VOLTAGE REFERENCE STANDARDS; CUSTOM BUILT TRANSFORMERS; SATURABLE CORE REACTORS

Can this new Rayotube mean better control of temperature in your plant?





In Henry Disston & Sons, Inc. plant, Rayotube in slab furnace roof needs no water-jacket against high ambient heat.

In spite of high ambient temperature, this Rayotube in roof of an open-hearth furnace has neither water-jacket nor air connection.

BUILT to detect temperatures for either Speedomax or Micromax Controllers, this new Rayotube No. 8890 has three features which help to improve the accuracy of control action.

1. The water jacket often needed for earlier Rayotubes is seldom required for this one because accuracy is not affected by ambient temperatures unless the head housing itself (shown above) exceeds 350 F. Omitting the jacket greatly simplifies installation and saves both water and maintenance due to water lines.

2. Overheating the Rayotube head to as high as 500 F does no harm; the accuracy decreases above 350, but returns fully as temperature drops. Thus, a few minutes' glare from an open furnace door does not affect the instrument's usefulness.

3. New, quick-sighting optical system for aiming the Rayotube at area of important temperature is especially helpful when aiming down an open-end tube to measure directly the surface temperature of parts being heated.

Catalog N-33B describes all Rayotubes as well as Speedomax and Micromax Pyrometers; we also can send description of this Rayotube only. Kindly address either our nearest office, or 4955 Stenton Avenue, Philadelphia 44, Pa.

Jrl Ad NS3(2)

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

LEEDS & NORTHRUP CO.

Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

ELECTRONICS

Electronic instruments have found their place alongside mechanical, hydraulic, and pneumatic instruments throughout industry and research organizations. There is no doubt that the application of electronic instruments in industry has reached the point where ALL the technical workers in our vast field need knowledge of the principles and operation of electronic equipment. Starting in July, INSTRUMENTS will publish a series of articles on Instrument Electronics. Each month one topic will be discussed and 30 to 50 multiple-choice test items will be asked on that topic. The answers to the questions will be published the following month.

The series will cover the principles and operation of electric circuits, vacuum tubes, and gas tubes. Amplification, oscillation, integration, and differentiation will be explained. Electronic instruments will be emphasized.

A tentative outline of the series includes:

1. Electrical nature of matter.
2. Electric circuit components.
3. Diodes and rectification.
4. Triodes, multigrid tubes, and amplification.
5. Gas tubes and ionization.
6. Amplifier circuits.
7. Oscillator circuits.
8. Thyratron circuits.
9. High-frequency heating circuits.
10. Timing and counting circuits.
11. Regulator circuits.
12. Oscilloscope and electronic instruments.

A Teaching Aid

An instrumentation approach can be a valuable teaching aid for teachers of science and engineering. For example, to tell a student that the mass of the hydrogen atom is 1.6×10^{-24} gram and that there are as many molecules of water in a drop of water as there are drops of water in Lake Michigan, may fill the student more with amazement than with facts. Facts in themselves cannot make a student capable in research and development technique.

However, when the student is told how the mass of the hydrogen atom or electron was derived, his natural amazement is replaced with facts and techniques that stick. Further, the instruments by which measurements are made and processes controlled should be built, torn apart, and worked on by all students in technical fields. Mathematics may be the language of engineers; instruments are their tools. More emphasis on instrumentation will produce better engineers and scientists. An instrumentation approach should be used in the teaching of both scientific and engineering subjects.

Announcement—

The Handbook of Measurement and Control IS ON THE PRESS

and will be distributed early this summer TO ALL SUBSCRIBERS

Dun's Review

The June issue of Dun's Review, the magazine for executives, has a full-page advertisement which illustrates graphically how Instrumentation can increase industrial output, product quality, and profits. This advertisement is first of a series paid for by *Instruments* magazine as a public service.

The first reaction of many of our readers may be that Dun's Review is a strange place to promote instrumentation. However, it is not enough that we in the field of Instrumentation tell ourselves through our publications about the power and versatility of instrumentation. We know how processes are made possible or more efficient by instruments, how the entire structure of science and engineering rests on instruments. In the past, however, many executives of industry have not been conscious of the power of increased instrumentation; too often the minimum instrumentation necessary to start production has been ordered for reasons of economy. Although events have shown the executives of industry that they cannot afford to economize on instruments, we are reminding them now that foresight is superior to hindsight.

In line with our policy of looking ahead as far as possible, we are bringing the facts about Instrumentation to the executives of industry, to the men who make decisions affecting entire industries—and thus, we hope, the instrument man's job will be made easier and receive greater recognition.

An Occupational Field

The term "occupational field" aptly describes the field of Instrumentation. This term is presented here because of the diversity of beliefs held by the men in the field. Some believe the field consists primarily of mechanics; others believe it to consist primarily of industrial process engineers; still others believe that research and development engineers are "the field." However, it is important for all the men in the field to realize that their field has grown to include tens of thousands of technical workers, and that each one is important and has something to offer all others. Men with several degrees in physics or engineering now spend all their lives developing highly specialized instruments. Other men are concerned wholly with the design of instruments and automatic controls for industrial process; others specify and purchase these devices for applications in research and industry; other men with mechanical skills spend their lives installing and maintaining instruments. All of these men are in the occupational field of instrumentation—M.H.A.

Two for One

The January issue of Instruments is in demand and the printer's supply is exhausted. We offer all subscribers who send us their January issue a two-month extension of subscription—and thanks.

An Electronic Control System *for* Industrial Control Applications

By ELWOOD T. DAVIS, Leeds & Northrup Company, Philadelphia

ABSTRACT.—Basic types of control action are defined and a new electronic control which provides the control actions is discussed in detail. The circuits which provide each type of control are discussed individually. An analogy is drawn between electric and pneumatic controls and the advantages of electric control are listed.

THIS article discusses a new and advanced electronic control system applicable to industrial processes. The system provides three control functions—proportional position, automatic reset, and rate control. Each function is discussed and defined briefly. The circuits are described in detail. The discussion is in terms of a fuel-fired temperature-controlled process, although the system is applicable to the control of pressure, flow, conductivity, pH of chemical solutions, or any measurable process variable for which there is a primary element with an electrical output.

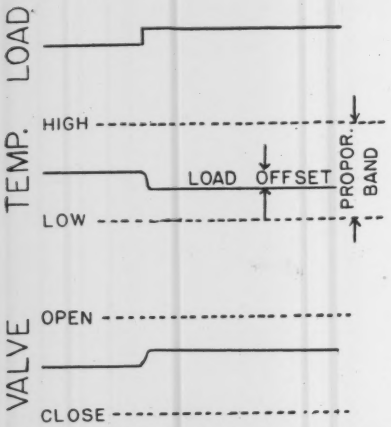


Fig. 1. Response of a proportional controller to a change in demand.

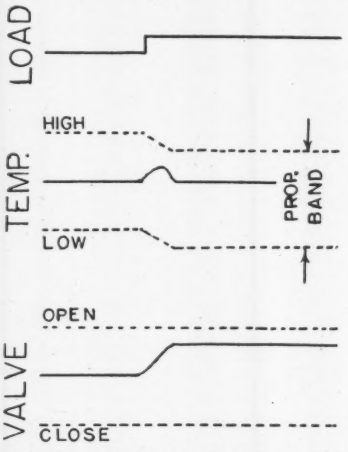


Fig. 2. Proportional plus reset action for load change.

Proportional Position Control

This control action, as its name implies, produces valve position which is directly related to the magnitude of the variable under control. Stated mathematically, proportional control may be defined as:

$$Y = -100 \times \theta / A,$$

where Y = Change in valve position (percent of full travel)

θ = Change in temperature (percent of controller scale)

A = Proportional band (percent of scale).

The minus sign in the equation for Y signifies that the controlled valve closes as the temperature rises. Thus the temperature variations and the resulting controller response can be said to be 180 degrees out of phase.

The proportional band is usually defined in percent of controller scale. For a 100-percent proportional band, for example, the valve is full stroked when the temperature changes by an amount equivalent to the full scale of the instrument. A 10-percent proportional band setting, on the other hand, produces full valve travel for a change in temperature corresponding to 10 percent of the instrument range.

Proportional position control, although entirely satisfactory for many processes, has one inherent weakness —*load offset*. For example, if the valve is controlled half open for a temperature of 210 degrees, the proportional-control action cannot provide for a new load situation in which the valve must be more or less than half open for a 210-degree temperature. Upon changes in demand, the valve assumes a new position to meet that demand, and this new valve position can only be secured at the expense of a change in the controlled temperature, as illustrated in Fig. 1.

This undesirable characteristic of proportional position control, which produces a different temperature for every change in load demand, is particularly objectionable where the characteristics of the process require the use of a wide proportional band and where consequently larger changes in temperature occur for a given change in demand. For such processes, or for other processes where a definite control point rather than a control band is needed, a second control function is used in combination with proportional position control. This control action is termed "automatic reset."

Automatic Reset

Automatic reset produces, in effect, an automatic reset of the proportional band with respect to the set point so

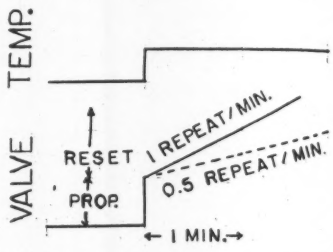


Fig. 3. Proportional control and two reset rates.

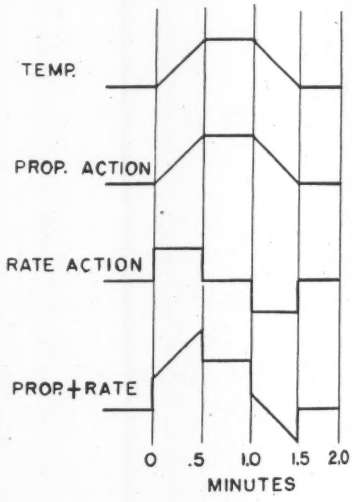


Fig. 4. Proportional plus rate action for load change.

that the control-valve position will be properly shifted with respect to recorder-pen position and hence temperature may be brought back to the set point regardless of changes in load demand, as illustrated by Fig. 2. That is, automatic reset produces a slow, continuous change of valve position, which persists as long as the temperature is off the set point.

Reset action recognizes only how far temperature is off the set point. It does not recognize the trend of temperature change. Unlike proportional action, which opens the valve for a downward trend in temperature and closes it for an upward trend, the rest action

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acts to move the valve at a given rate in the same direction for a given deviation of temperature on one side of the control point regardless of trend.

It is of interest to note that automatic reset, due to its integrating action, is out of phase with the temperature and lags the temperature cycle. For example, on sinoidal variation in temperature, a corresponding sinoidal variation in reset-control action is obtained which lags the temperature cycle by 90 degrees.

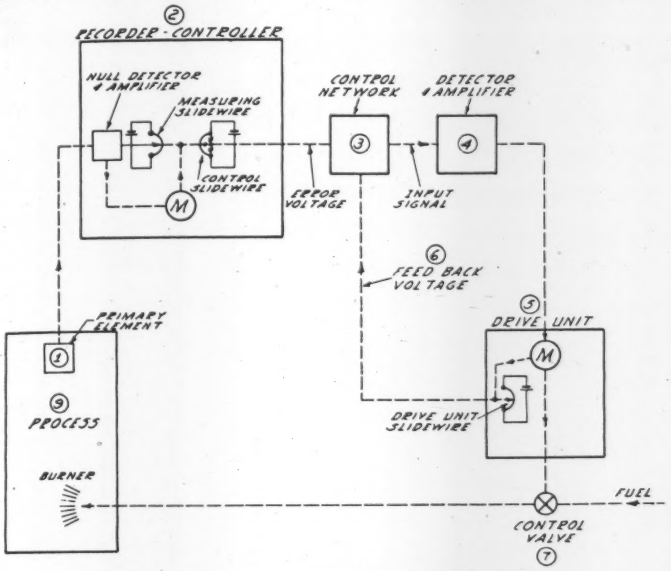

Fig. 5. Components of the Series-50 Electric Control.

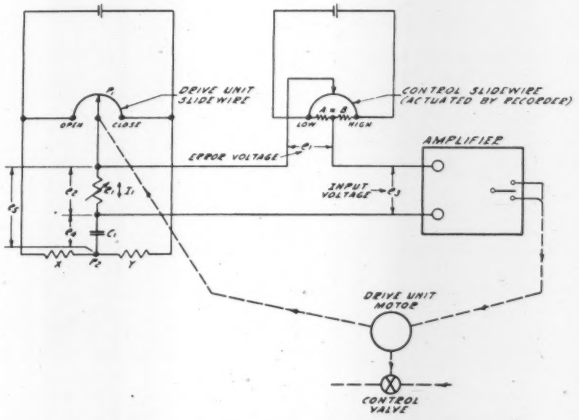

Fig. 6. Proportional position control circuit.

Due to the out-of-phase action of reset, the reset action is inherently unstable and tends to cause cycling of the control. However, when used in combination with the stabilizing effect of proportional action, stable control can be secured.

The speed of reset action is generally defined in *repeats per minute*—that is, the number of times the proportional valve action is reproduced by the reset action in one minute. This is illustrated by Fig. 3.

Where measuring and control lags are short, relatively fast reset rates may be employed; where lags are longer, the reset speed must be reduced to avoid hunting.

Rate Action

The latest control action to be used for industrial control is termed "rate action." This is almost always used in conjunction with proportional action and usually in combination with proportional plus reset.

Rate action recognizes the *rate of change* of the process measurable (temperature) and produces a corrective valve action proportional to the speed with which the temperature is changing.

Rate action is illustrated in Fig. 4.

Rate action is usually expressed in terms of time. *Rate time* is the time by which the valve action has been advanced as compared to the time it would have reached a given position with proportional control action only.

Rate action is out of phase with the temperature. However, it is interesting to note that contrary to reset action, which lags the temperature cycle, rate action leads the temperature cycle. As the control action due to rate *advances* valve action, it provides a very valuable addition to the overall control action, particularly where appreciable lags are present in the measuring system.

The addition of rate action often results in reducing the magnitude of temperature departures to a given load swing by a factor of 2 to 1, and the time required to restabilize at the control point by a factor of 3 or 4 to 1. Consequently, this effective control action has become an essential part of a modern control system.

It is interesting to note that the lead and lag of rate and reset actions operate together in such a way that the unfavorable lag characteristics of the reset action are partially offset by the rate action. This permits using faster rates of reset, the increase being in the order of 1.7 to 1.

With the fundamental control principles in mind we now come to a description of a new advance in electric control systems which incorporates all the control actions.

Series-50 Electric Control

The major components of the Series-50 Electric Control are shown in Fig. 5. An error signal is developed whenever the controlled variable departs from the set point. The control unit uses the error signal to provide proportional, reset, and rate actions.

Primary element (1) transmits the input signal to the standard recorder-controller (2). This unit has a motor which positions the control slidewire to a position corresponding to that of the measuring slidewire. Any motion of the control-slidewire contact from its midposition produces an *error voltage*, which is transmitted to the control network (3).

The control network compares the error voltage and a feedback voltage from the drive unit (5) to develop a second error signal, which is the input signal to the detector-amplifier (4). If the input signal to the detector is other than zero, the corresponding output signal actuates the motor of drive unit (5), thus generating a feedback voltage (6) by movement of the drive-unit slidewire and a corresponding mechanical repositioning of the control valve. The change in input restores the process to such a condition that the error voltage is reduced to zero.

The system of Fig. 5 represents two closed-loop systems,—one, the control system only, including items (3), (4), (5), and (6); the other including control valve (7), the burner (8), the process (9), primary element (1), and recorder controller (2).

Proportional-Position Control Circuit

Fig. 6 is a simplified diagram which indicates the functioning of the proportional-position control circuit only.

The control slidewire which is positioned by the recorder generates an error voltage, e_1, when the slidewire

contact is at any position other than its midposition. This is because resistors A and B are equal.

If e_1 is other than zero, then unless e_2 is equal in magnitude to e_1 and of opposite sign, the input voltage e_3 is other than zero. The detector and amplifier then produce an output voltage to operate the drive-unit motor in one direction or the other. As the drive-unit motor operates, it moves its slidewire contact with respect to its slidewire so that a voltage difference between P_1 and P_2 appears across resistor R_1. When this feedback voltage e_2 is equal and opposite to error voltage e_1, then input voltage e_3 becomes zero and the drive-unit motor stops.

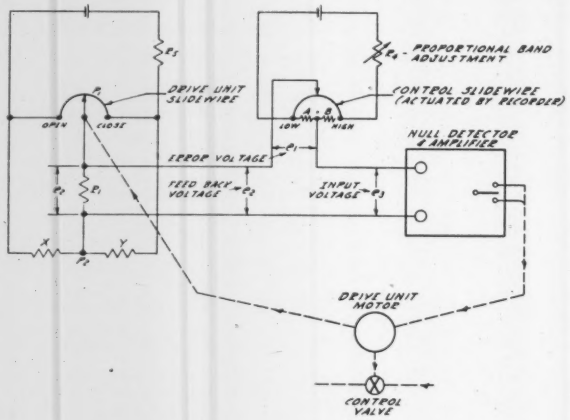

Fig. 7. Proportional plus reset control circuit.

If the control-slidewire contact is at its midposition (e_1 = zero), then the drive-unit slidewire is at its midposition (e_2 and $e_3 = 0$). Likewise, as temperature departs from this midposition and generates a voltage e_1 proportional to this departure, the valve-slidewire contact must be moved to generate a voltage e_2 proportional to drive-unit position in order to maintain input voltage e_3 at zero. Consequently, proportional position control is obtained.

The width of the proportional band is a function of the relative voltages on the control and drive-unit slidewires. For example, if each slidewire had 1 volt across it, then a 1:1 ratio would be established and full travel of the control slidewire would produce full travel of the valve slidewire, giving a proportional band of 100 percent—assuming the width of the control slidewire corresponds to full recorder scale.

As resistance R_4 is decreased by turning the proportional-band adjusting dial so that the voltage across the control slidewire rises from 1 volt to 10 volts, then one tenth of the control-slidewire travel generates the 1-volt signal required to full stroke the drive unit. Accordingly, the proportional band is then 10 percent.

Automatic-Reset Circuit

By a simple modification of Fig. 6, as indicated on Fig. 7, automatic-reset action is produced.

The modification is the addition of capacitor C_1. Capacitor C_1 makes it impossible for the drive-unit slidewire to maintain feedback voltage e_2 to rebalance e_1 except by a slow but continuous change in slidewire position in the proper direction to restore temperature exactly to the control point.

Assume that the temperature departs from the control point as a step function and observe what takes place. Upon a step departure of temperature from the control point, the error voltage e_1 increases to a fixed value. This signal, applied through the amplifier, immediately actuates the drive unit to generate voltage e_2 until it is equal in magnitude and of opposite polarity to e_1. This is the proportional position action.

Note that e_2 is generated by an IR drop across resistor R_1 due to the flow of current I_1. The current I_1 flows because of the difference in voltage e_5 which exists between potential points P_1 and P_2. Since this path includes capacitor C_1, any voltage on the capacitor, e_4, influences the magnitude of current I_1 for a given potential e_5. It is evident that as current I_1 flows thru C_1 a potential e_4 is built up on capacitor C_1 which opposes the flow of current, that is:

$$I_1R_1 = e_2 = e_5 - e_4$$

Hence as e_4 increases, e_5 must increase to keep e_2 constant. Therefore the drive unit must move continuously at a slow speed to increase e_5 at the same rate that e_4 is increasing in order to maintain e_3 at zero.

Linear reset through entire range of valve action.—The rate of increase of potential e_4 is constant for a given departure from the control point because $E = Q/C$, and the charge Q on capacitor C increases at a uniform rate because of constant current I_1. The increase in e_5 similarly is a linear function because e_5 is related to e_4 by an assumed constant difference e_2. Therefore, for a given temperature deviation, the speed of valve action due to reset remains constant throughout the entire valve range.

Reset speed proportional to deviation.—Note that the speed of valve action due to reset is proportional to the magnitude of the deviation of temperature from the control point because as e_1 becomes larger with greater deviation, charging current I_1 must be larger to develop a correspondingly larger I_1R_1 drop to balance e_1. This increased current charges C_1 at a correspondingly faster rate and causes e_4 to build up proportionally faster. Accordingly, voltage e_5, which is determined by the drive-unit slidewire-contact position, must be increased at a similar faster rate.

Reset Adjustment.—Adustment of reset is accomplished readily by a variation in the value of resistor R_1. Referring to Fig. 7, it is apparent that if R_1 is halved, I_1 must be doubled to produce the same I_1R_1 drop, e_2. The increased current charges C_1 at twice as fast a rate as before. Therefore, the reset speed is doubled. A wide latitude of reset adjustment can thus be provided by varying R_1 from a very low value to an extremely high value.

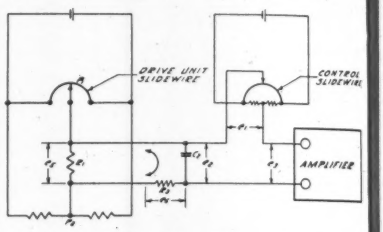

Fig. 8. Proportional plus rate control circuit.

Rate-Action Circuit

Rate action generally is used in conjunction with proportional position action. It operates to add a further increment of valve action as a function of the *rate of change* in temperature. The magnitude of rate action is defined in terms of time—the rate time being the difference in time for the valve to reach a given position with rate action compared to the time for the valve to reach that position by proportional-position only.

In order to provide a control action proportional to rate of change of error voltage e_1, it is necessary to add only a resistor and a capacitor to the proportional positional control diagram of Fig. 6, which appears on Fig. 8 as R_3 and C_2.

Rate action is produced if rebalancing voltage e_2 is attenuated with respect to its source voltage e_5 when a change in temperature requires a change in e_2. Network R_3 and C_2 is designed to produce such attenuation of e_2. Furthermore, to produce valve action proportional to the rate of change of temperature, network R_3 and C_2 not only must produce a difference in voltage between e_5 and e_2, but on the other hand there must be no difference in voltage between e_5 and e_2 under constant conditions of e_1 and e_2.

When e_1 is maintained at a constant value, that is with temperature steady, e_2 will likewise be constant and the charge on capacitor C_2 will then be equal to e_2. Zero current then will flow

in R_3. Voltage e_5, which is a function of drive-unit position, will then be equal to e_2 and a normal proportional relationship between e_1 and e_5 will exist.

Now if the temperature begins to change at a constant rate, e_1 begins to change at a constant rate. A similar rate of change in e_2 will be demanded by the control system in order to keep amplifier input-voltage e_3 equal to zero. In previous circuits, before the addition of C_2 and R_3, it was necessary only for the drive unit to change P_1 an amount proportional to the change in e_1 to rebalance e_2 to equal e_1. However, it will now be noted that capacitor C_2 is subjected to a changing voltage e_2 and, therefore, charging current I_2 flows into C_2. The path of this charging current may be traced from slidewire contact point P_1, thru C_2 and R_3, to potential point P_2. This charging current produces a voltage drop in resistor R_3 so that e_5 must be made greater than e_2 by the magnitude of this voltage drop. Consequently, the drive-unit position must be advanced beyond the position which otherwise would have been required to generate voltage e_2; the magnitude of this advance is determined by the voltage drop e_6, which occurs as an I_2R_3 drop in resistor R_3.

The magnitude of I_2 is determined by the rate of voltage rise required in capacitor C_2 to balance the rise in voltage e_1. The faster e_1 changes, the greater the charging current I_2, and the greater the voltage e_6. Accordingly, the valve action is advanced over its normal proportional position action as a function of the rate of change of temperature.

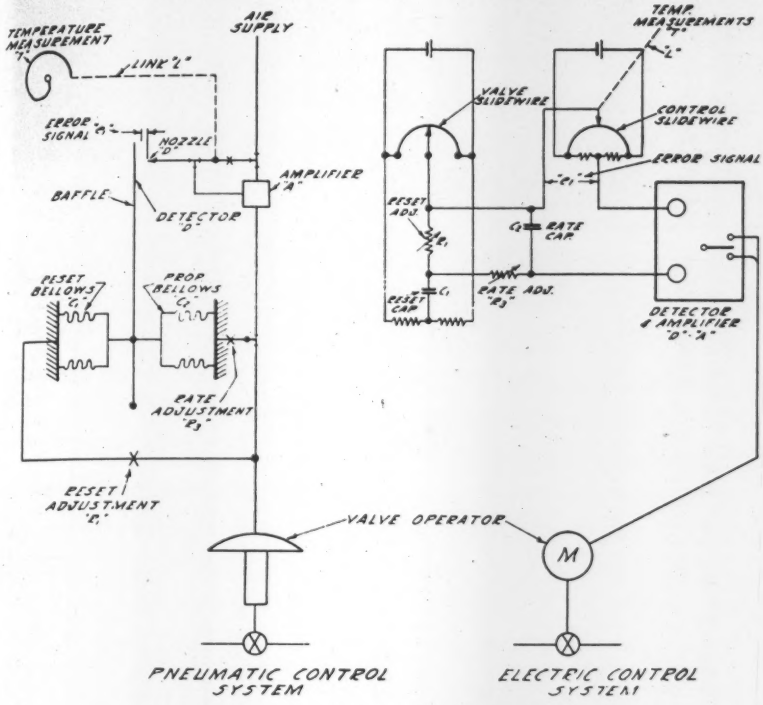

Fig. 9. Analogy between electric and pneumatic control systems.

Rate-time adjustment. — Adjustment of rate time is accomplished readily by a variation in the value of resistor R_3. Note from Fig. 8 that the magnitude of the advance of the drive-unit slidewire voltage is proportional to the value of voltage drop e_6 across R_3. That is, for a given value of I_2 required to produce a given rate of change in e_2, the magnitude of voltage e_6 is directly related to the value of R_3.

An analysis of the circuit shows that the value of resistor R_3, in megohms, to produce any desired value of rate time is:

$$R_3 = \text{Rate time} \times 6$$

Note that the time constant of the RC network producing rate action, expressed in minutes, is equal to the rate time in minutes.

Electric and Pneumatic Controls

An analogy between this new electric control system and a simplified diagram of a pneumatic control system is shown in Fig. 9.

Temperature-sensing element T of the pneumatic system produces, by means of mechanical link L, a physical displacement of nozzle N to produce an error signal to the pneumatic detector, which consists of the nozzle and baffle. On the electric system similar letters indicate parts performing similar functions.

The detector output, after being boosted by the amplifier in the pneumatic system, operates the valve and also is fed into the proportional bellows thru rate restriction R_3, the rate restrictor serving to delay the pressure impulse to detector D. Note that this is analogous in the electric system to the amplifier output operating the valve and also generating valve response e_5, the response of the amplifier to e_5 being delayed by resistance R_3. Capacitor C_2 simulates the air capacity of the proportional bellows.

In the air system the proportional response gradually bleeds thru reset restriction R_1 into reset bellows C_1, which acts slowly to cancel out the force of the proportional bellows. This is analogous in the electric system to the flow of current thru R_1 into reset capacitor C_1, the effect of which is to slowly build up a potential which cancels out the proportional signal voltage.

It is of interest to note that just as it is essential to have the reset system of the pneumatic control tight to prevent air leakage, so also it is important to have reset capacitor C_1 of the electric system designed to have negligible leakage. This is particularly true in both control systems when the reset rate is slow—that is, when reset resistance R_1 is large.

Advantages of Electric Control

1. *Permanent calibration.* — In the electric system, where resistors and capacitor values can be readily controlled, the control-response dial calibrations can be accurately determined and maintained constant. Variations may occur in a pneumatic system due to dirt in the air clogging small orifices.

2. *Linear response.*—The pneumatic system uses a compressible fluid. It is therefore subject to inherent changes in rates of flow thru a given orifice restriction as the flowing pressure changes. These changes are appreciable over the usual working range of three to fifteen pounds output. In the electric system a linear rate of reset is available over the entire valve range.

The same is true also for rate-time calibration, as the electric system is unaffected by compressibility effects.

3. *Single power supply.*—A source of electric energy usually is needed for the measuring system. If the control system also is electric, then one power supply suffices for both purposes. For pneumatic systems a source of air is required in addition to an electric power supply.

4. *Reliable power source.*—An air supply may fail due to cold weather freezing the moisture in the air-supply line or to dirt clogging the lines. Electric power is free of these hazards.

5. *Readily serviced.*—Electric systems lend themselves to unitized designs in which various units or components can be plugged together or separated quickly for servicing. Fig. 10 indicates how plug-in technique has been used for components and chassis of this controller.

Fig. 11 indicates front view of control showing provision for Auto-Manual transfer and means for reading valve position. This is accomplished by oper-

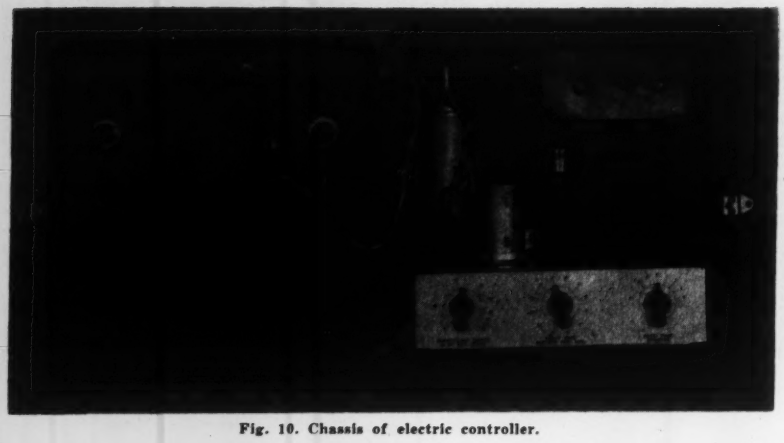

Fig. 10. Chassis of electric controller.

ating READ VALVE POSITION knob and then turning upper valve pointer until signal lights indicate a balance.

6. *Transmission lag.* — Electrical transmission is not subject to the lag of an air system. This is of particular importance on fast-responding processes such as flow control.

slidewire PS, which is driven either at various linear rates or by cam actuation at any desired nonlinear rates.

In a cascade control system one instrument can reset the control point of another instrument simply by suitable operation of slidewire PS by the second instrument.

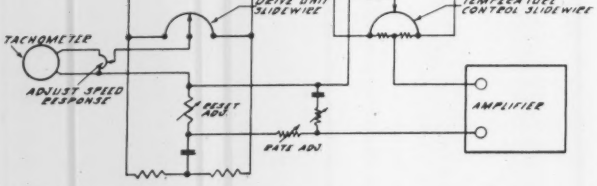

Fig. 12. Electric control of speed.

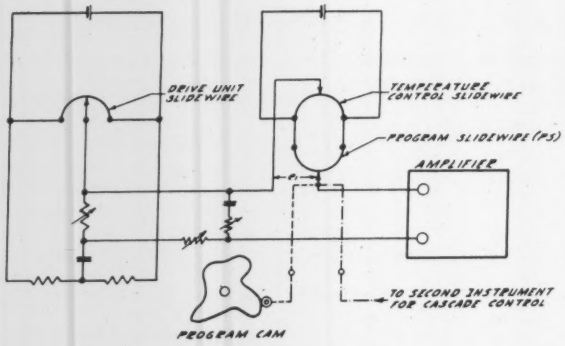

Fig. 13. Program control.

7. *Flexibility.*—The electric system is extremely flexible from the standpoint of combining other features into a standard control system. For example, Fig. 12 indicates how a proportional speed response can be tied into the control system. Such an arrangement would be of value in regulating fuel input to a furnace not only as a function of the measured temperature but also as a function of conveyor speed.

Fig. 13 indicates how simply a program can be incorporated in the standard system by the addition of program

Test Results

Application of hundreds of these controls throughout industry have already proven the worth of this new system.

Fig. 14 is a typical example of the improvement effected by use of the new three-function system as compared to the previous two-function control. As will be noted, not only is the response to control point changes more rapid and stable but also disturbances due to periodic door opening are greatly reduced. Due to the improved execution

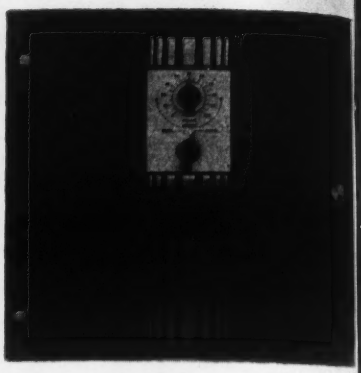

Fig. 11. Front of electric controller.

of the control action and the addition of the rate function it was possible to reduce appreciably the proportional band and to increase the reset speed.

In conclusion, electric control has a definite place in industry not only for the type of process usually encountered but particularly for the more complicated jobs where it can be readily tailored to fit a particular application.

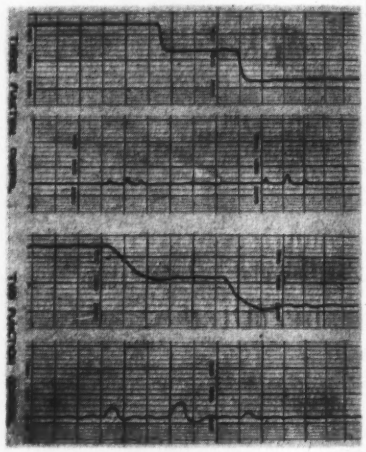

Fig. 14. Comparison of response with new and old systems.

For mathematicians, the control equation of the controller is:

$$\frac{dP}{dt} = S(1+RTa) \times \left[\frac{R\theta}{1+RTa} + \frac{d\theta}{dt} + \frac{T\frac{d^2\theta}{dt^2}}{1+RTa}\right]$$

where P = Valve movement in percent of total travel.
θ = Deviation from control point in percent of chart.
R = Reset rate in repeat/min.
S = Reciprocal of proportional band in percent.
T = Rate time in minutes.
a = Controller constant $= (C_1 + C_2)/C_1$.

Pneumatic Servomechanisms *in the* Iron *and* Steel Industry

By A. A. MARKSON, Hagan Corporation, Pittsburgh, Pennsylvania

ABSTRACT.—Advantages and limitations of air as a control fluid in a servomechanism are listed and described. The transmission factors associated with pneumatic signals are discussed, including the pressure range used and the speed of transmission. Typical oil-operated and air-operated servomechanisms for controlling the heavy damper of a furnace are shown, together with the relative advantages and disadvantages of each type. The design problems for air-operated power units are discussed, including the high-inertia load problem and damping.

Introduction

THE term "servosystem" refers to a mechanism whereby a power-amplifying device is regulated by the error or discrepancy between a controlled variable and the control point. A servomechanism in a continuous control system is a closed-loop system—that is, a system in which the difference between the actual control point and the desired control point is the error signal, which continuously controls the mechanism. The military services have made remarkable accomplishments in the field of closed-loop servosystems. Although the specifications and conditions with which iron and steel engineers are concerned differ widely from those of military engineers, the remarkable developments by the military are of great importance to industrial engineers.

A servomechanism compares two quantities or conditions and develops an error signal that drives the mechanism. The error signal and driving signal can be electrical, hydraulic, or pneumatic. This paper discusses the factors associated with the use of pneumatic systems—that is, systems which use air as a control fluid.

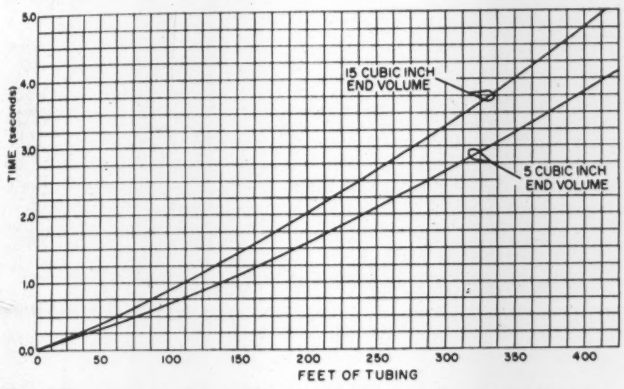

Fig. 1. Time constant of a 0.25-in. pneumatic transmission line with two end volumes.

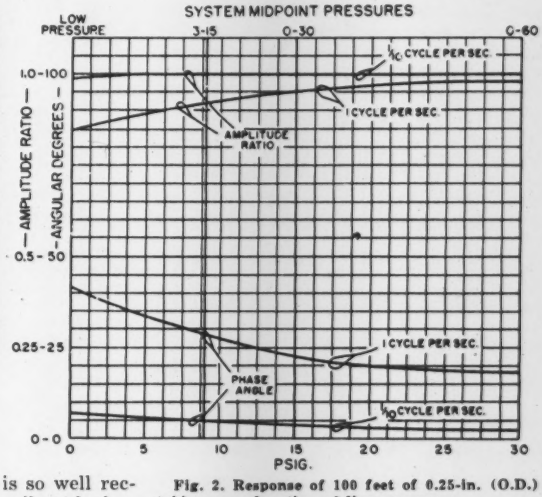

Fig. 2. Response of 100 feet of 0.25-in. (O.D.) tubing as a function of line pressure.

Advantages and Limitations

The principal advantages of air as a control fluid are:

1. Air is a low-cost consumable fireproof fluid requiring no return piping.

2. For continuous signal transmission, especially in multiple-loop systems, air is unexcelled for moderate transmission distances. Compared with incompressible liquids, air has no hydrostatic head and temperature problems. Compared with modulated electrical-signal systems, the receiving and transmitting servos are simple and inexpensive. This advantage is so well recognized that present-day oil and electrical systems use air signal-transmission extensively.

3. Air power units ordinarily have a lower ratio of inertia to peak thrust than geared electric drives.

4. Air power units have certain practical advantages over oil units. These advantages are due to the fact that an elastic fluid is used for prime-mover power generation. As power-cylinder work is done by fluid pressures and volumes, the mass flow of air is smaller than that of oil for the same volumes and pressure levels. Pressure drops in pipes are proportional to the square of the volume flow and the fluid density. Thus, high volume flows give much lower pressure drops for air, which has a lower density than oil. This means smaller lines, smaller relay systems, and smaller valve porting. Hydraulic accumulators are often uneconomical and cumbersome, and the hydraulic pumping is continuous whether the power units are consuming fluid or not. Compressed-air receivers, on the other hand, are advantageous and practical.

The principal limitations of air as a control fluid are:

1. The necessity for a reliable weather-protected air supply requires a well-engineered compressed-air supply. Indiscriminate use of ordinary mill air supplies has been a factor in past disappointments.

2. For high-speed control applications, especially where long lines are involved, the capacitance characteristics of air transmission can be a limiting factor. For such applications, systems operating at high pressure levels and having large air-handling capacities are required. Transmission lines must be terminated by devices of negligible volume. In certain cases, newly developed electro-pneumatic transmission links can replace excessive lengths of air line.

3. Air lacks the high inherent damping and lubrication characteristics of oil. This must be overcome, especially in the design of power units.

Transmission Characteristics

Pressure range.—Industrial systems for transmission of pneumatic signals make use of numerous pressure levels. The I.S.A. recommended standard of 3-15 psi. is in wide use. However, both higher and lower pressure systems are in extensive use for signal transmission. The highest pressure-range in wide use is about 0-60 psi.; the lowest in use is about 0.5 psi. Inverted ranges, such as 60-0 psi., are also employed widely, principally to give receiver

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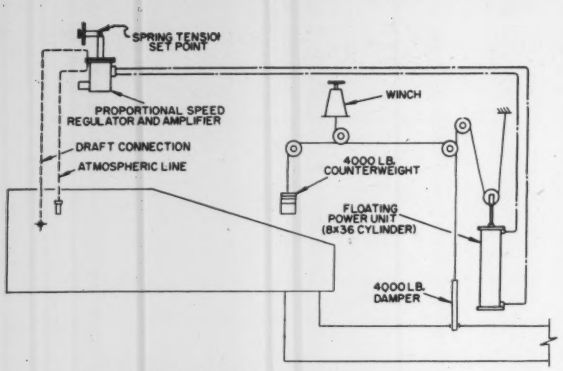

Fig. 3. Hydraulic furnace-pressure control.

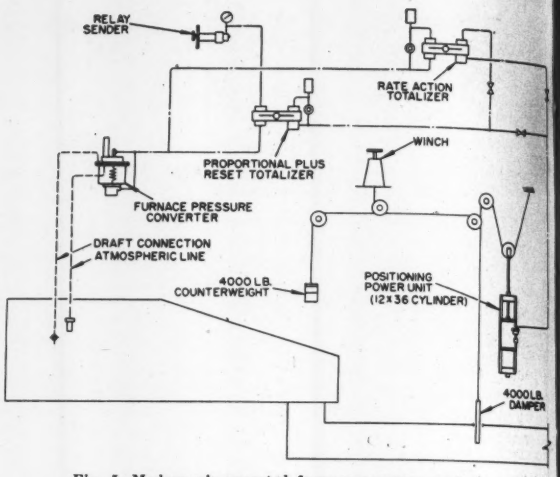

Fig. 5. Modern air-operated furnace-pressure control.

devices an inverted direction of motion for increasing signal. The advantages of a biased transmission system, such as 3-15 psi., result from the fact that the low end of the range is not at atmospheric pressure level. However, the disadvantage of a biased system is the more complicated system required for combining signals and handling the bias pressure.

Speed of transmission.—Although an air transmission-line is analogous to a resistance-capacitance transmission element, the line has characteristics which depend on the pressure level. Like a spring, the "stiffness" of air increases with the pressure. Also, the flow and resistance characteristics are linear over only limited intervals. Thus the response characteristics of a line to a step variation in input depend on the magnitude and location of the step variation. Fig. 1 illustrates the time constant (time for impulse to reach 63 percent of its final value) for various lengths of 0.25-in. (O.D.) copper tubing with two end volumes. A 0-15 psi. step input was used.

A recent paper by Iberall,[1] of the Bureau of Standards, has remarkably improved the quantitative analysis of air lines by using a frequency-response approach to the problem. This paper solves the problem of expressing an air transmission-line as a graphic transfer-function which is bounded by pressure level and valid over a limited disturbance range. Fig. 2 was derived from Iberall's paper to show the influence of transmission level on the design of controls. A 100-ft. length of 3/16-in. (I.D.) tubing was assumed to be terminated by a negligible volume. A sine-wave input of small amplitude about a mean pressure level is understood. The attenuation and angular lag of the output pressure-wave are plotted against the mean pressure for frequencies of one cycle per second and one cycle in ten seconds. It is evident that the use of high-pressure transmission results in less attenuation and less angular lag—that is, fast control around the control point.

The speed-of-response requirements of a servomechanism depend on the process response. Theoretically, a process can be made to respond as fast as desired by the application of high energy at high rates to the process. In practice, however, limitations always occur. For example, in a continuous galvanizing furnace, rapid change of tank temperature can be produced only by fuel-firing rates which are destructive of the tank. Limitations on energy supply rates exist in every physical installation.

When it is desired to drive a given process at higher recovery rates by means of an automatic control-loop, the attending increases of phase-angle lag in the process make it essential for control-circuit delays to be small.

The important subject of frequency response and speed of air-control devices is one with many ramifications. A great variety of these devices is available, including practically every kind of signal convertor. Computing elements which perform algebraic and functional operations, including linear multiplication and division of signals, are available both as specialized components and as combination devices. Program and other types of input devices are available also. The application of these devices in multiple-loop circuits is rapidly gaining headway in industrial process control.

(1) "Attenuation of Oscillatory Pressures in Instrument Lines" by Arthur S. Iberall, Journal of Research of the National Bureau of Standards, RP2115, Vol. 45, July 1950.

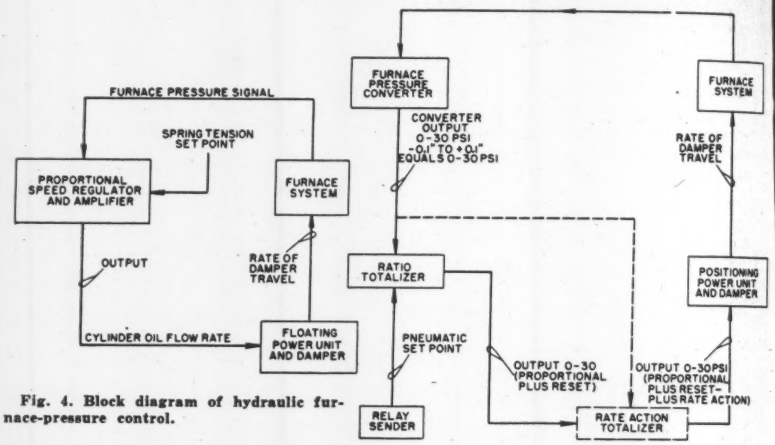

Fig. 4. Block diagram of hydraulic furnace-pressure control.

Fig. 6. Block diagram of air-operated furnace-pressure control.

Heavy-Damper Controls

A typical oil-operated control for an open-hearth furnace-pressure stack-damper is shown in Fig. 3. The block diagram of the system is shown in Fig. 4. The slide damper is a water-cooled steel and brick structure, which operates with loose guiding. Such dampers can weigh about 4000 lbs. and have dimensions of 6 x 8 ft. A counterweight system ordinarily is employed to relieve the manually-operated winch of dead-weight load.

The power unit must be able to move the damper through its full 6-foot travel, although in practice full opening seldom is required.

The oil-operated control system of Fig. 3 uses a double-reeved cylinder having a bore of 8 in. and a stroke of 36 in. This cylinder is powered by a proportional-speed oil controller and relay, which has a capacity of 12 gpm., at 100 psi.

The cylinder displacement is about 1800 cubic inches. At a maximum flow of 12 gpm., or 2800 cubic inches per minute, the minimum time for full stroke is 38 seconds. Thus the maximum piston speed is 57 inches per minute, which occurs at no load on the cylinder.

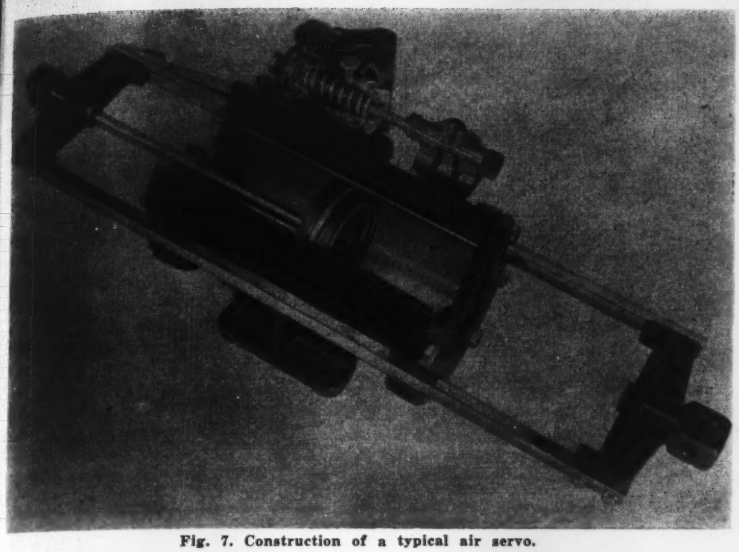

Fig. 7. Construction of a typical air servo.

The product of piston area and 100-lb. oil pressure gives a peak thrust of 5000-lb. force. This is the stalled thrust of the cylinder, or the zero-speed thrust characteristic.

The damper weight of 4000 lbs. usually is balanced by an equivalent counterweight so that the inertial system consists of a mass of 8000 lb. The system is double reeved so that the 8000-lb. mass during acceleration appears to the cylinder as though a 32,000-lb. balanced mass were connected directly to the rod.

The controller is a proportional-speed regulator which establishes a rate of oil flow proportional to the difference between the furnace pressure and the regulator setting. The full range of operation is usually about 0.2-in. water. The limiting control speed usually is established by the cylinder oil consumption. The oil cylinder requires full-time pump operation, the oil being bypassed when not used by the regulator.

The air-operated counterpart of this hydraulic system is shown in Fig. 5. Fig. 6 is the block diagram of the pneumatic system. This system uses a 12-in. x 36-in. positioning air cylinder. The no-load traversing time is 10 seconds.

The furnace-pressure converter changes furnace pressure into an air-pressure signal between 0 and 30 psi. This signal is fed into a *ratio totalizer regulator*, the set point of which is adjusted pneumatically from the control panel. A proportional-plus-floating response is transmitted to the air servo, which has a type of rate action superimposed when desirable. The control sensitivity is better than 0.001-in. water.

The air control is about twice as fast as the comparable oil control in operation. However, the air system uses more complicated apparatus than the oil system. The faster response introduces a major inertial problem, which was minor in the slower oil system. Two major benefits result—(1) a non-inflammable and cheaper control fluid is used, and (2) the control response during transients is improved greatly.

Power Units

As early air cylinders proved inadequate for handling heavy inertial loads which were combined with stickiness, it was felt by many that a power unit operated by an elastic fluid was inherently a poor device for heavy work. Instability of a power unit under an inertial load is an unpleasant experience. Big dampers build up fairly fast oscillations without warning. When this happens, the cylinder acts as though it had been taken charge of by the damper. The term "chugging" has been used to denote this situation.

Five years ago many thought that the advantages of compressed-air systems —high control speed and freedom from hydraulic-fluid troubles—were doomed by the stability limitation. Further, frequent minor maintenance on air cylinders was annoying even though it was realized that a single bad leak on a liquid system usually resulted in very important maintenance expenditures

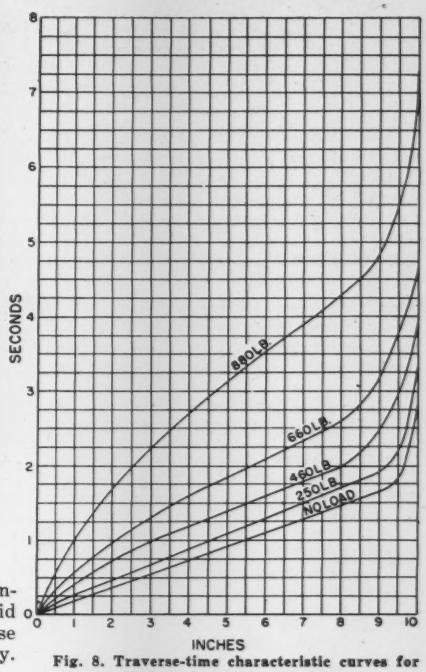

Fig. 8. Traverse-time characteristic curves for a power cylinder with various loads.

and production losses. However, it can be said today that air-operated power units are now well established in the industry. The inertial load-stability problem has been solved by cylinder design and application techniques. A typical air servo is shown in Fig. 7.

The inertia problem.—Fig. 8 is a set of characteristic curves of a 5-in. x 10-in. positioning air-operated power cylinder, using 100-psi. air. Piston displacement and time are plotted for suddenly applied full-range positioning inputs to the cylinder, which is lifting weights. The linear sections of the curves correspond to steady speed. For this condition, the piston thrust is determined by the attached weight and the lever arm.

Fig. 9, which is plotted from the steady-speed data of Fig. 8, gives a typical cylinder-thrust vs. speed characteristic. The curve of useful horse-

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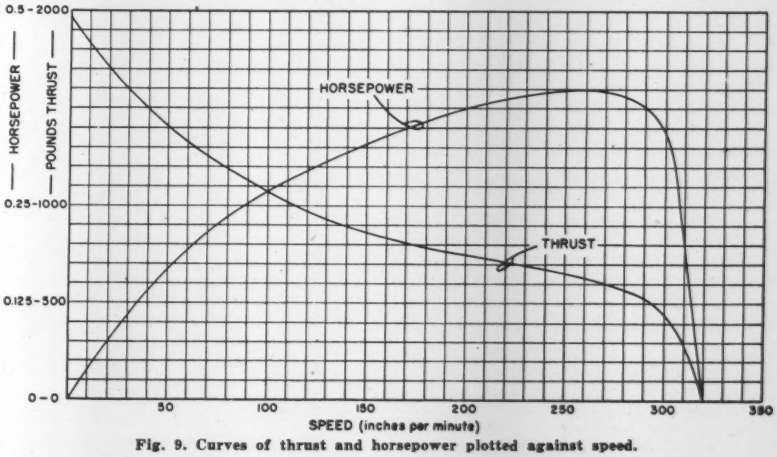

Fig. 9. Curves of thrust and horsepower plotted against speed.

Hydraulic Servocontrols *in the* Steel Industry

By H. ZIEBOLZ, Askania Regulator Company, Chicago

ABSTRACT.—The advantages and disadvantages of hydraulic servosystems are explained and a method for obtaining proportional-plus-reset control with a hydraulic system is shown.

HYDRAULIC servos are hydraulic regulators which amplify the signals to be controlled and which apply this amplified signal to the control valve, damper, or mechanism to reduce an error signal to zero.

Requirements of Industrial Servosystems

Servocontrols for the steel industry require (1) relatively high power level (typical torques from 1000 to 25,000 in.-lbs. and higher, and forces up to several tons), (2) sturdy construction of all components, as rough handling is to be expected (including exposure to wide ranges of temperature, vibration, dust, gases, and so forth), (3) continuous operation with minimum maintenance, (4) simplicity of circuits, and (5) easily understandable operation (a requirement not always identical with the simplicity specification).

Hydraulic Amplifiers

The main reason for the successful use of hydraulic equipment in these applications is the inherent characteristics of hydraulic relay devices. We shall, therefore, briefly review the relays most commonly used in hydraulic servos.

The relay shown in Fig. 1A is the well known *four-way valve*—a spool which controls through its displacement (S) access and relief of oil pressure to a double-acting piston.

In a similar manner the *throttle valve* in Fig. 1B varies the pressure between a fixed orifice and the outlet it controls by its displacement (S). By applying the supply pressure of the pump to the area of the small piston, and by applying the pressure varied by the movement (S) to the large area, a balance is obtained only for one position of the throttle valve and a motion of the piston in either direction, depending on the variation of (S).

In Fig. 1C a *jet pipe* is moved relative to two receiving orifices, the impact pressures of which vary linearly with the displacement (S) of the jet.

In all three relay valves the floating speed of the cylinder is directly proportional to the displacement (S), a characteristic which is typical of the hydraulic relay and which is most desirable from a standpoint of stability. As the error signal decreases, this characteristic causes a reduction of control speed, which prevents overcontrol and diminishes inertia effects.

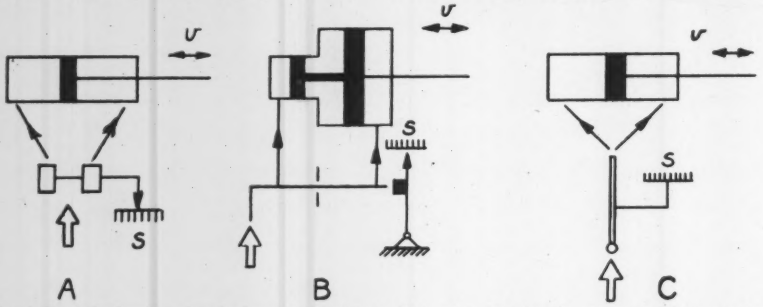

Fig. 1. Basic hydraulic-relay devices. A, Four-way pilot valve; B, throttle valve; C, jet-pipe relay.

The disadvantage of the four-way pilot valve (Fig. 1A) is relatively large friction-dynamic unbalance and high mass of the spool. The advantage of the jet pipe (Fig. 1C) is extreme simplicity, low inertia, and low "noise level"—that is, low level of minimum forces or moments to be overcome by the applied signal.

As the oil pressure required sometimes is higher than the capacity of the jet pipe, a pilot valve of type 1A is arranged in series with the jet. This adds the unlimited size and pressure range of the pilot valve to the characteristics of the jet, but avoids the drawbacks of the pilot valve alone. This is accomplished by coupling the jet with the pilot valve as shown in Fig. 2.

The jet (A) in Fig. 2 delivers its oil at a pressure of from 100 to 200 lbs. into two adjacent orifices, which are part of a movable piston (B). By connecting the orifices to opposite sides of (B), a displacement of the jet results in a pressure differential which moves the piston and its orifices in a direction to make it coincide again with the jet-pipe nozzle. Thus the piston follows every motion of the jet-pipe nozzle.

The power level of the piston (B) overcomes the friction level and the dynamic unbalance of the four-way spool (C) and thus avoids the high "noise level" which occurs when the signal is applied directly to the four-way valve. If rotary motion is required, hydraulic motors with pressure inputs up to 3000 lbs. can be operated successfully with such devices.

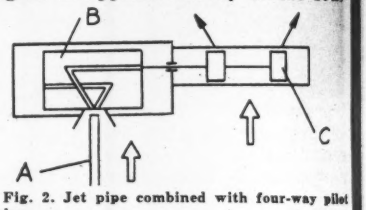

Fig. 2. Jet pipe combined with four-way pilot valve.

Performance of Hydraulic Servos

Fig. 3 shows a typical performance curve, which illustrates the performance obtainable by means of hydraulic servos. The box representing the servo (a positioning device in this instance) is subjected to sinoidal signal-input variations at various frequencies. The input and output amplitudes are measured, as is the phase displacement in degrees between the output and the input. The top curve in Fig. 3 shows the ratio of output to input amplitudes at various frequencies. The bottom curve shows the phase displacement between the output and the input.

At zero and low frequencies the output/input ratio of amplitudes is unity. The ratio becomes slightly more than unity at about 600 cycles per minute because the servosystem has a resonant response at that frequency. The output

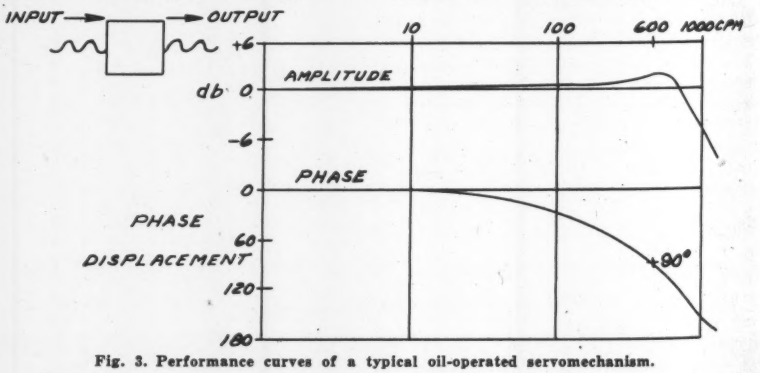

Fig. 3. Performance curves of a typical oil-operated servomechanism.

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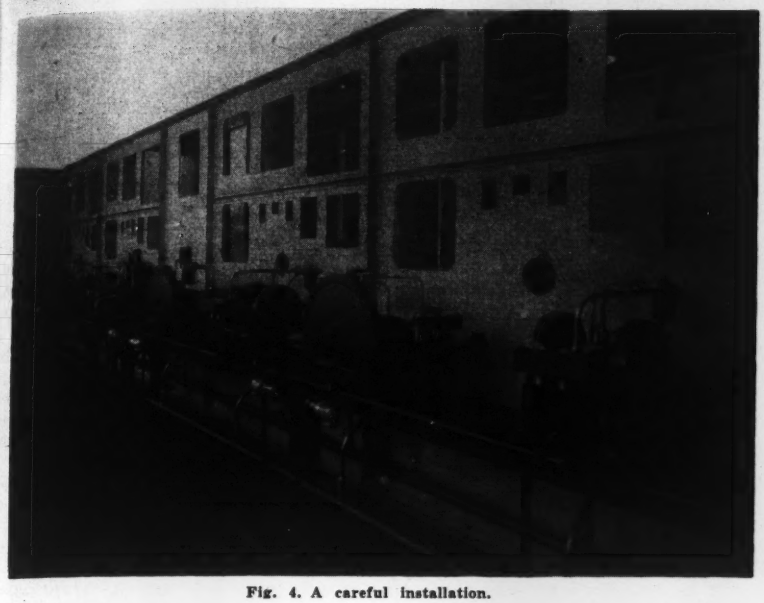

Fig. 4. A careful installation.

drops off above about 800 cycles per minute, and the output lags the input by 90 degrees at 600 cycles per minute, or 10 cycles per second.

It is possible to make the amplitude response of such hydraulic servos uniformly flat up to 100 cycles per second. Such performance is practically unobtainable at present by other servomechanisms available.

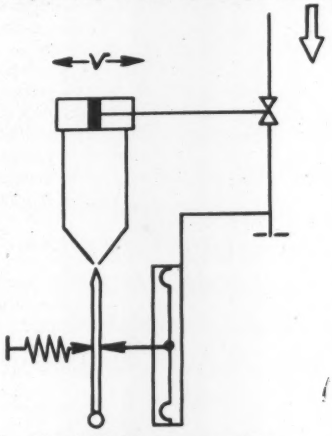

Fig. 5. Floating-type regulator.

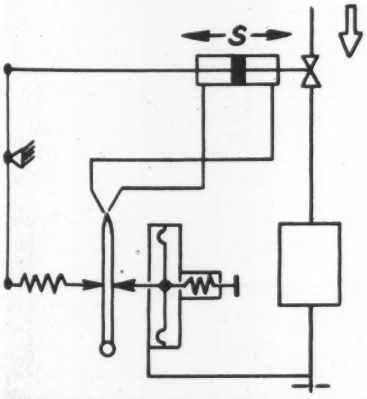

Fig. 6. Proportional-position regulator.

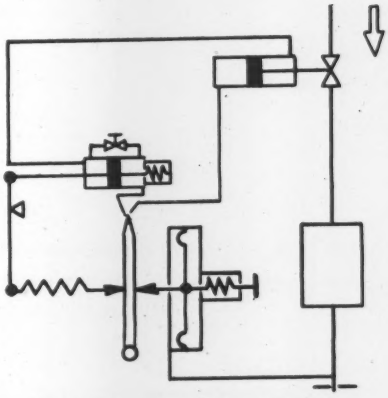

Fig. 7. Proportional-plus-reset regulator.

Inherent Characteristics of Hydraulic Servos

The reason for this performance can be found in some basic characteristics of hydraulic servos. These are:

1. High ratio of acceleration to inertia.
2. High starting torque without danger of overload or overheating.
3. High deceleration rate because the fluid also acts in the system as part of a dash pot.
4. Convenient reduction of speed or wide range of speeds, including zero.
5. Self-lubrication—when oil is used as the operating medium.
6. Practically instantaneous transmission of power due to incompressibility of fluid.

The disadvantages of hydraulic systems are:

1. The need of a source of oil under pressure and with sufficient capacity.
2. A careful job of installation and housekeeping to avoid leaks. (Fig. 4 shows a careful installation with minimum amount of piping.)
3. Fire hazard if oil is used as an operating medium.

The first two difficulties can be overcome by a careful planning of the installation and its maintenance. The fire hazard can be avoided by the use of noninflammable liquids which have recently been used in hydraulic systems. As difficulties with packings and corrosion have been overcome by choice of suitable materials, it is expected that these noninflammable fluids will play a bigger role in hydraulic systems as they become available at lower cost.

However, as speed governors on high-temperature turbines prove, it is possible to design hydraulic circuits which are safe even for operating conditions where a loss of oil could become a potential danger. This fact is borne out on aircraft which use hydraulic servos to a great extent under difficult operating conditions and within wide ranges of temperatures.

Modes of Control

Hydraulic regulators are used whenever positive forces or torques are needed at high power-level and with high acceleration. Examples of such applications are (1) flow controllers for liquids and gases, (2) turbo controllers, (3) furnace-pressure controllers, (4) desuper-heaters, (5) high-pressure boilers, (6) arc-furnace and electrical load controllers and (7) web-guide controllers.

Floating.—The controller used for such applications usually uses the simple *floating*, or *proportional-speed* mode of control, which is shown diagrammatically in Fig. 5. As the pressure on the spring-biased diaphragm increases, the error signal applied to the jet moves the piston in the direction for closing the supply valve. This floating-control mode produces a *rate* of valve movement which is proportional to the *error*.

Proportional position.—If the time constant of the process is slower than that of the floating regulator, stability cannot be obtained with the floating mode of control because the control overshoots its proper control point. To overcome this, a proportional control is used in which the valve *position* (S) is made directly proportional to the error signal. As shown in Fig. 6, this is done by feeding a signal representing the valve position back in opposition to the error signal.

Reset.—To correct for the resulting load droop which is inherent in the proportional mode of control, *proportional-plus-reset* control is used, as shown in Fig. 7. The figure differs from Fig. 6 in that the direct feedback link between valve position and jet-pipe position is replaced by a positive displacement meter—a bypassed piston in series with the controlling piston.

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NON-CONTACT GAGING

By J. T. WELCH, Sheffield Corporation, Dayton, Ohio

ABSTRACT.—This article discusses the X-ray gage for measuring the thickness of continuous strip, and the air gage for measuring the thickness of fabricated parts. The principles, construction details, and numerous applications are presented.

X-RAY GAGING OF STEEL STRIP

NON-CONTACT gaging is an accurate, foolproof, and fast means of measurement.

There are two generally known types of non-contact gages for continuous strip—X-ray tube and "I-so-tope." The I-so-tope, which uses a radioactive isotope as a source of radiation, is more commonly known as a *beta-ray gage*. The speed and depth of penetration of the I-so-tope usually is not as great as the X-ray gage. However, there are many applications for the I-so-tope.

Commercial interest and acceptance of X-ray gages started about 1940. Since that time over a hundred successful installations have been made. There are four different types of circuits available from various manufacturers.

The first type, which we shall call type "A", employs one X-ray tube, which sends a portion of the beam through a tapered wedge. The wedge is automatically indexed to the proper position (for the thickness of stock to be checked) by means of a setting dial. Electronic circuits are used to give an indication of material thickness in thousandths, either on a meter or on a recorder.

The second type (type "B") employs two X-ray tubes. One sends its beam through a master sample and the other through the material to be measured. A reading of material thickness is obtained by comparison.

The third type (type "C") also employs one tube. The beam is split, as in type "A", but inserted master samples are used for each thickness or type of material to be gaged.

The fourth type (Fig. 1) is entirely electrical and electronic. It employs one small X-ray tube, which is built into the high-voltage transformer. By having the tube in the transformer, all high-voltage cables are eliminated. The beam is shot through the material to be measured. The amount of rays not absorbed are compared with pre-determined settings. The difference between what is absorbed and what the electronic circuit indicates should be absorbed is indicated or recorded in terms of percent deviation from the nominal thickness. If desired, one pen of a two-pen recorder can be used to record the thickness to which the instrument has been set, and the other pen can give the percent deviation from the nominal thickness. This gage is described in detail in this paper.

All types of X-ray gages should have a set of master samples, which are used periodically for checking the calibration of the instrument. Accuracies of the various X-ray gages vary from one to four percent depending on the type of material being measured, type of unit, thickness of stock, and conditions of operation.

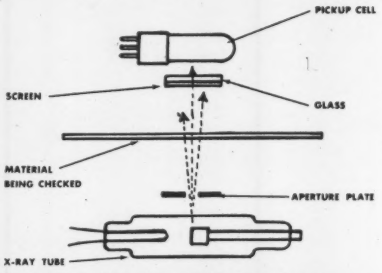

Fig. 1. Principle of the X-ray gage.

Fig. 2. "Measuray" X-ray gage.

Construction details of Measuray X-ray gage.—Ability to withstand mill operation is important. The Measuray X-ray gage (Fig. 2) can be used on any mill, including the hot mill, where it is exposed to cobbles, water sprays, mill oxide, and heat from the steel being rolled.

For ease of servicing, all controls and circuits are in the power-supply cabinet, which can be mounted at a distance from the mill. A block diagram of the components of the gage is shown in Fig. 3.

Pickup unit.—Only the X-ray tube and transformer are mounted in the lower part of the pickup unit. Low-voltage cables and connections for the coolant used in cooling the transformer are connected to the unit. No high-voltage cables are required because the transformer is in the pickup unit. As the lower half of the unit is underneath the run-out table, it is not likely to become damaged. The over-arm is exposed, but it contains only the photo-electric pickup cell used to detect the rays not absorbed by the material being gaged. A small cable runs from the over-arm to the power-supply cabinet. There can be as much as 30 inches between the bottom end of the photo-electric pickup cell in the over-arm and the aperture in the base unit.

By removing all electronic circuits from the pickup unit and over-arm, costly components can not be damaged. If it is necessary to replace the over-arm, it can be done in the mill with little time, trouble, and expense. The entire unit usually is mounted on a slide which is either manually, mechanically, pneumatically, or hydraulically controlled to move the unit across the

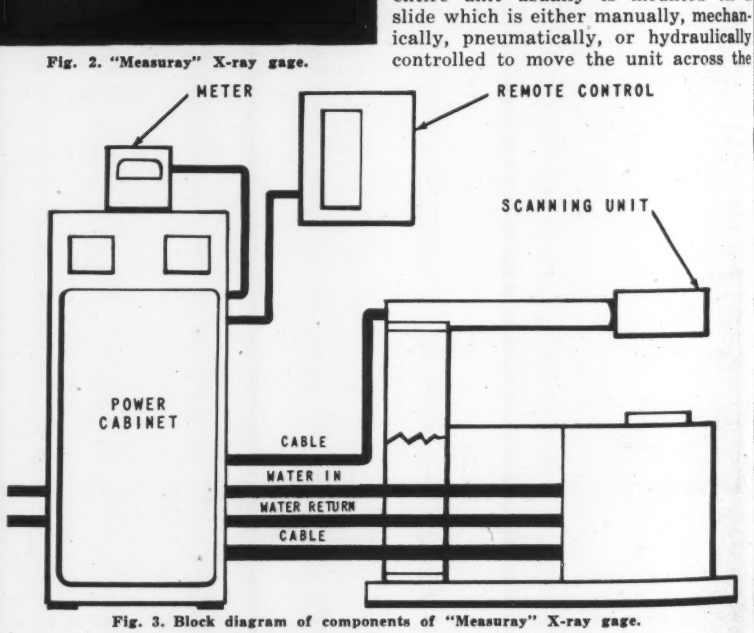

Fig. 3. Block diagram of components of "Measuray" X-ray gage.

Paper presented at the Conference "Instrumentation for the Iron and Steel Industry," sponsored by the Carnegie Institute of Technology and the Pittsburgh Section, Instrument Society of America, March 28 and 29, 1951, Hotel Roosevelt, Pittsburgh, Penna.

Fig. 4. X-ray gage on an electrolytic tin line.

sheet. This permits the operator to explore or check the crown in the sheet or move the unit off the mill table.

Although the X-ray tube usually is mounted underneath the run-out table, it can be mounted at any angle to suit the application without affecting the accuracy. Fig. 4 shows an application on an electrolytic tin line.

Applications.—There are many sizes and types of X-ray gages available. The Sheffield Corporation manufactures six different types. One or more of these models can measure from the thinnest of stainless steels up to ½-in. plate. Recorders provide a continuous record.

X-ray units are used also to operate throw-out gates for sorting purposes; under- and over-size material are sorted into one pile, whereas material within the range passes on to the next operation. X-ray gages prevent re-runs on orders and enable the mill operator to be "on gage" at least by the end of the first slab. Gages also save equipment on which the steel is reduced further. For example, the life of cold mills could be extended and maintenance reduced if the steel coming to the mills were more uniform in thickness.

Another application is that of mill control. In some applications, the signal from the gage has been used to control the roll setting, which determines the thickness of the material. Although this problem is not completely solved, many mills will be automatically controlled within a few years.

Some manufacturers have installed the "Measuray" ahead of punch presses to protect dies. One concern estimated savings of $2000 per month on die repair by setting up an X-ray gage to control stock going into the presses.

In the steel mill, the X-ray gages are used on electrolytic tin lines, annealing furnaces, skin-pass mills, cold-sheer lines, cold mills, stainless-steel mills, and hot mills. Gages are used also for controlling punch presses and slitters, and for checking and sorting sheet stock. They are used also on many homogenous nonferrous materials such as Vinyl plastic, hot and cold brass, aluminum, rubber, and paper.

Fig. 5. Column-type air-gage.

One interesting application indicates how close an X-ray gage can measure. The glass in automobiles is a laminated unit composed of two sheets of glass with a film of plastic between them. Striations of only a few tenths of a thousandth in the plastic cause defective glass. When the plastic causes faulty safety glass, the glass manufacturer charges not only the cost of the plastic to the supplier but also the amount involved in processing the glass sheet to the point where the rejection occurs. Naturally the plastic supplier is rather meticulous in his inspection. The X-ray gage is used to pass or reject the plastic.

Safety.—The X-ray beam is controlled automatically. As soon as the sheet passes out of the gage, the instrument automatically either shuts off or reduces the X-ray intensity to such a low point that is is no longer harmful. It can be turned on again either automatically by means of the load relay on the mill or manually by use of reset on the control panel.

Stray Radiation is so small that a man could work within eight to twelve inches of the unit eight hours every day and not receive any harmful effects. Measurements made at the Cleveland Clinic proved that the scattered radiation is much less than the permissible dose of 0.1 roentgen per eight-hour daily exposure. Only in the immediate neighborhood of the vertical beam, with the X-ray tube operated at maximum capacity, could any scattered radiation be detected. Even under these extreme conditions, the radiation scattered by a steel filter amounted to only 5 milliroentgens per hour, or 0.04 roentgens for a continuous exposure of eight

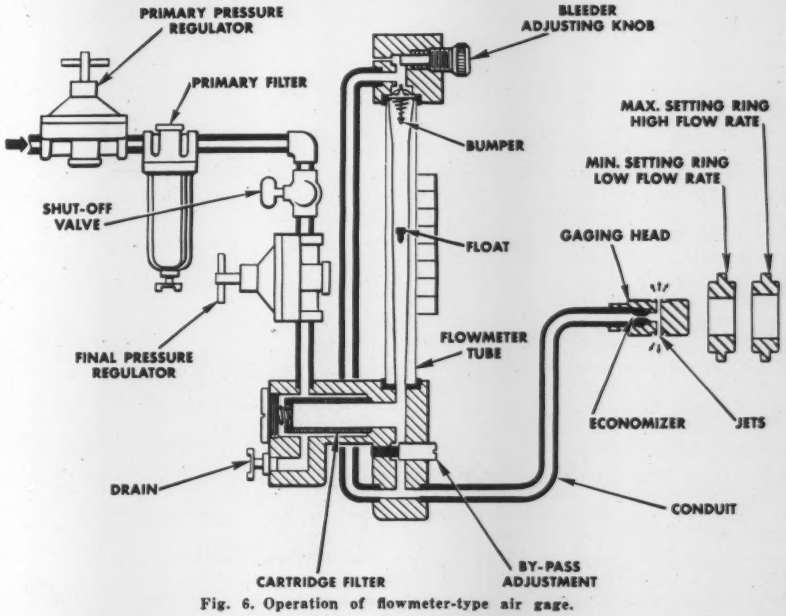

Fig. 6. Operation of flowmeter-type air gage.

hours. This is less than half of the permissible daily tolerance dose.

At greater distances from the beam, the scattered radiation intensities amount to only small fractions of the tolerance dose. For all working locations around the X-ray unit, protection against scattered rays was found to be thoroughly adequate.

Air-gage Measurement of Fabricated Parts

Pneumatic comparator—The pneumatic comparator, generally called an *air gage*, employs an air jet for measuring fabricated parts. A column-type air-gage is shown in Fig. 5.

When a surface approaches the nozzle of an air gage, the discharge of air from the nozzle to the atmosphere is controlled by the clearance between the surfaces and the nozzle. Visual indication of the nozzle clearance is made by using a flowmeter in one type of system and a Bourdon tube or bellows in another type. The air gage in Fig. 5 is a flowmeter type. The air jet usually is located in the plug for internal measurements; a C-shaped snapring is used for external measurement. The flow of air emanating from the nozzle and escaping through the clearance between the spindle and part is indicated, thereby giving a precise and accurate measurement of the dimensions of the part. The principle of operation of the flowmeter-type air gage is shown in Fig. 6.

Operation.—In operation, compressed air is supplied to a filter and then to a regulator, which reduces the line pressure to the pressure required by the instrument. From the regulator, the air passes through the tapered glass tube and out through the nozzles in the plug, ring, or C-shaped spindle. The air flow (or pressure) depends on the proximity of the gaging surface to the jet. A change in flow of air changes the position of the float in the glass tube, which is tapered, being smaller at the bottom than it is at the top. Therefore, the float rises to a point in the tube where the diameter accommodates the volume of air flowing.

Magnification of as much as one hundred thousand times can be obtained by a float-type instrument such as a gage-block comparator. Magnifications of twenty thousand to one are used regularly in production of fuel-injection parts, for which the diameter of pump plungers can be specified to 0.000005 inch. Readings are accurate and fast; as many as three thousand operations per hour can be gaged with relatively unskilled help. Most instruments have calibrated scales to indicate the physical dimensions of the part.

Applications.—The pneumatic comparator can be used to explore internal diameters, either one at a time or several simultaneously. Taper, roundness, straightness, and diameter of a single unit can be checked by moving the spindle through the part and rotating the part or spindle. Alignment of main bearings in motor blocks is inspected

Fig. 7. Air-gage equipment for checking valve seats.

by a 4-column instrument on the production line. Air gages are used for checking squareness, straightness of one bore to another, one external surface to a diameter, and one internal surface to an external surface or a combination of surfaces.

The position of the work is not an important factor in a gaging operation. A decided advantage of flow-type units is the ability to apply the gaging member to the component while it is still in the machine. This is done by connecting the gaging head to the base instrument by means of a plastic hose. The length of this hose does not affect the speed of response in measurement.

A true-diameter reading can be obtained by using two jets. A clover-leaf pattern can be inspected by three jets. An average diameter can be measured by using a multiple number of jets.

When measuring an internal dimension, the plug is always underneath the minimum dimension of the hole size being gaged. This permits easy entry, increases wear-life and assures fast, accurate inspection.

Fig. 7 shows air-gage equipment for checking the seat of exhaust and intake valves for a reciprocating engine. The pilot on the end of the air gage spindle is inserted in the valve-stem hole. The air jets measure any eccentricity between valve seat and stem hole.

Fig. 8 shows how it is possible to eliminate the sorting and classifying of inner and outer races separately by

Fig. 8. Air-gage equipment for measuring difference in raceway diameters of a bearing.

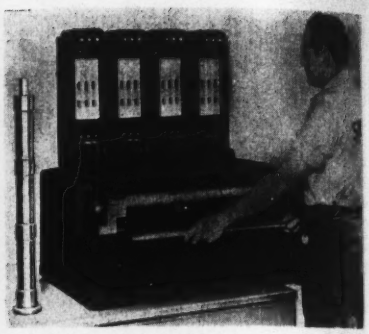

Fig. 9. Air-gage equipment for inspecting crankshafts.

measuring the difference in diameter between one raceway of the inner race and that of the outer race. The difference in diameters is recorded directly in ball size, thereby reducing radial play from 0.0003 to 0.0001 inch. The use of a fixture of this type, with either a column or dial-type air gage, enables the manufacturer to reduce his inventory by as much as 50 percent and to speed his inspection by 33 percent.

Fig. 9 shows a set-up for inspecting a crankshaft. All main bearings are checked on one instrument. Each bearing has 3 sets of jets to give an inspection at three points on each main bearing. If all three floats for any one bearing are in the same plane, the operator has a straight-line indication in front of him, which tells him the bearing diameter and that the bearing is straight. Should the middle float be at a higher position than the ones on each side, he knows that he has a convex condition, and that the center part of his bearing is larger in diameter. Should this float be lower than the other two, it means his bearing is concave in the center. If the floats give an angle line, whether up or down, it tells him the bearing is tapered. All of these facts can be known in less than 30 seconds.

Fig. 10 shows equipment for checking the internal bore of a motor block.

Continued on page 691

Fig. 10. Air-gage equipment for checking the internal bore of motor block.

Radiographic Inspection *of* Steel Castings

By JOHN M. FLANAGAN, Pittsburgh Ordnance District, Department of the Army, Pittsburgh, Pennsylvania

ABSTRACT.—This article presents a history of radiographic inspection, compares the various radiographic methods in general use, and explains the importance and use of contracts and specifications in radiographic inspection.

THIS article is based primarily on the viewpoint of an Ordnance inspector. Ordnance inspection personnel are trained not to become technicians primarily, but to interpret specifications, to read drawings, and to learn techniques necessary for the acceptance of material meeting specific requirements. Most castings now being produced in the Pittsburgh Ordnance District for Army Ordnance are homogeneous armor steel. All castings are required to meet ballistic tests. The tests for penetration and shock or impact are very rigid, requiring not only a heat-treated alloy steel, but a product with sound sections. The most troublesome defects, such as gas inclusions and centerline shrink, can be detected by radiography. Radiographic inspection is an important means for controlling quality. Other non-destructive tests used in locating defective areas, including Magnaflux and reflectoscope methods, are mentioned briefly.

History of Radiographic Inspection

Prior to the beginning of the last war, radiographic inspection was employed only sporadically by the steel-casting industry. One reason for this was that many foundries dealt only with commercial castings, which were designed with sufficient factor of safety to offset the characteristic defects found in their product. The general practice was to section a pilot casting before placing the pattern in production to determine the correctness of the foundry procedure and the quality of the article. This was not only costly, but it is questionable if the results obtained justified the means.

It is doubtful if there is another industry in which there are so many variables which affect the quality of its product as in the steel foundry. These variables include location of heads, gates, and chills, condition of sand, proper drying of the molds, pouring temperature of the metal, and the design of the casting to be produced. The design factor, which is a responsibility of the engineer, received little consideration in the past. However, both the relation of heavy and light sections and the proper fillets at adjoining sections have a direct bearing on the resultant soundness of the casting.

In recent years the foundries, through their associations, have had extensive development programs to reduce the defects that affect the soundness of their product. The foundryman now realizes the importance of proper sand-control. New types of alloys have been developed. Heat treatment and melting techniques have reached the stage where the metallurgist is a necessary and important member of the foundry staff.

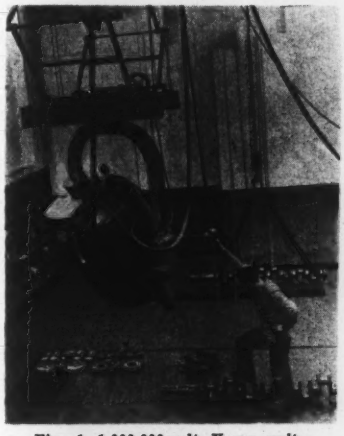

Fig. 1. 1,000,000-volt X-ray unit.
(Photo courtesy General Electric X-Ray Corp.)

The Ordnance Department realized the importance of steel castings for material. As a result, the Army, in 1922, installed the first modern high-powered X-ray machine at Watertown Arsenal. This machine utilized a potential of 200,000 volts, sufficient to penetrate approximately 2 inches of steel. Since then, a 1,000,000-volt machine, capable of penetrating 6 inches of steel has been installed. This arsenal at one time specialized to some extent on producing fabricated gun carriages and artillery items which required extensive weldments. The X-ray was found indispensable in determining the acceptability of the welds.

The Ordnance Department specifies a 140-kv. machine for steel sections up to 1 inch, 200-kv. up to 2 inches, 220 kv. up to 3 inches, 300 kv. up to 3.5 inches, and 400 kv. up to 4 inches.

About eight years later, the Naval Research Laboratory employed gamma rays for the first time in the examination of large and complex sections. These were stern-post sections of the heavy cruisers of early-1930 programs. It was found that this method penetrated much thicker sections than the most powerful X-ray machine then available.

In recent years the development of both X-ray and gamma-ray methods of radiography has been rapid. Recently the *betatron* has been made available with a potential up to 22,000,000 volts.

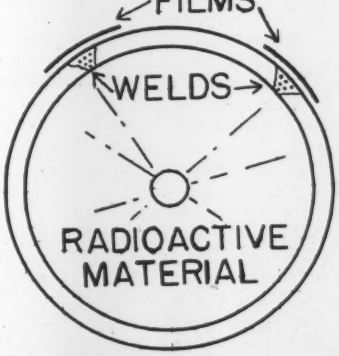

Fig. 2. Radiography with radium or artificially-radioactive material.

Comparison of Radiographic Methods

The X-ray has advantages and limitations compared to the gamma ray. As it has greater sensitivity, it discloses smaller defects. Its disadvantage is the difficulty encountered when radiographing a casting with widely varying thickness. Separate exposures are necessary for each section, requiring extensive blocking to eliminate secondary radiation. Secondary radiation is probably 50 percent of the total radiation striking the film. With the gamma ray, however, secondary radiation is only one or two percent, giving more clarity of detail with castings of widely varying thickness.

As the gamma ray is much less sensitive than the X-ray, it requires extremely long exposures. However, it is without competition up to this time in the examination of very heavy sections. This is said with reservations because of the advent of the betatron. The gamma-ray capsule is portable and simple to use. Interpretation is more simple than with the X-ray because sections of varying thickness can be radiographed simultaneously.

In Ordnance work, the choice between the X-ray and gamma ray is left to the producer or contractor. When the time element affecting production schedules is the dominating influence, the X-ray is used.

The *betatron* has some advantages over both X-ray and gamma ray. It is very fast and has little or no secondary radiation, thus eliminating the need for blocking the film. It can penetrate much heavier sections—the 22,000,000-volt machine can penetrate approximately 28 inches of steel in several minutes. However, the betatron is less mobile than the X-ray machine. It is

Continued on page 688

Paper presented at the Conference "Instrumentation for the Iron and Steel Industry," sponsored by the Carnegie Institute of Technology and the Pittsburgh Section, Instrument Society of America, March 28 and 29, 1951, Hotel Roosevelt, Pittsburgh, Penna.

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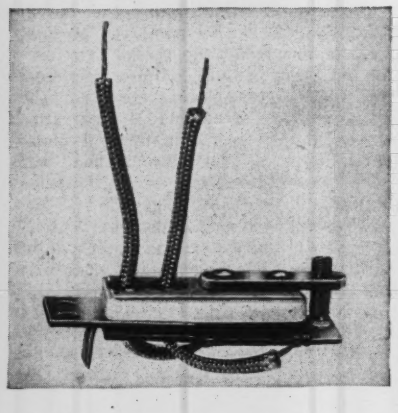
Provide timing ranges of 2 seconds to 3 minutes



★ These miniature units actually require a space less than 1⅜" x ⅝" x ½", yet the sturdy design contributes to long life.

A Steatite base provides dimensional stability while mounting is accomplished thru a Bakelite bracket which furnishes complete insulation as well as elimination of pressure on the ceramic member. Electrolytic silver contacts insure best conductivity and longer operation. Stable adjustment is provided for by the clinch-type bracket which holds the adjustment screw. Contact rating is 100 watts 115-230 volts ac.

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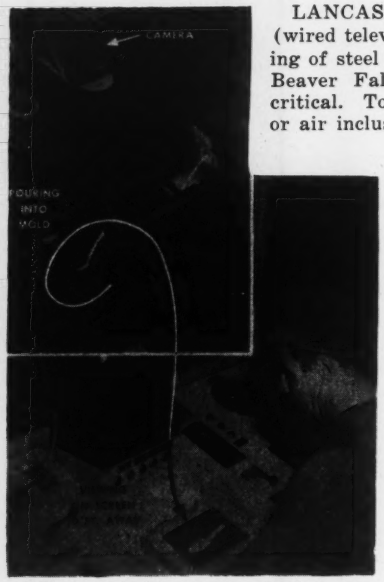
INSTRUMENTS ON THE MARCH

Television Aids Steel Making



Utiliscope television system, showing camera and viewing screen.

LANCASTER, Ohio.—The Diamond "Utiliscope" (wired television) is now used in the continuous casting of steel billets at the Babcock & Wilcox Tube Co., Beaver Falls, Pa. The pouring operation is very critical. To get good billets without spongy spots or air inclusion, the mold must be kept full to a certain level. Formerly, it was necessary to station a man directly at the mold top to watch the pouring and to signal the operator, who was 50 feet away. There was always the possibility of a misunderstanding, the hazard was very high, and the discomfort from radiant heat was large.

Now, as shown in the illustration, a "Utiliscope" camera with a long-focus lens is suspended above the molten-metal surface in the mold. The camera transmits a continuous picture of the molten-metal level to the viewing screen, which is placed in the control panel, as shown in the illustration. The operator watches the pouring at close range in safety and comfort. Camera and viewing screen are connected by coaxial cable. The "Utiliscope" is a television system that transmits by wire instead of by broadcast.

Glass Valves *for* Vacuum Control

WASHINGTON, D. C.—One of the problems encountered in vacuum practice is the ready and accurate control of gas flow into or through the system. It is important that the device used for such control should not be a source of contamination and should not liberate unwanted gases. The standard stopcock normally used for this purpose has been found unsatisfactory because its grease seal does not permit application of the high heats necessary for degassing. This results in undesirable contamination and the grease itself is a source of trouble.

R. Forman of the National Bureau of Standards has developed a glass-seal type of valve which operates at pressures of the order of 10^{-6} mm. of mercury. The new valve depends on the expansion of glass or metal when heated. This elongation breaks a glass seal which separates the vacuum system from another of higher pressure. When the source of heat is removed, contraction of the glass reseals the system.

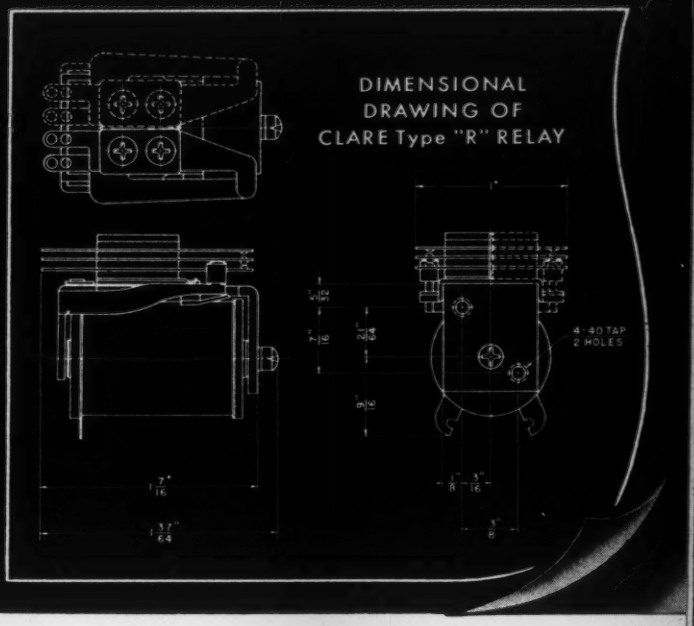
The valve has the appearance of a conventional water condenser with but one side-arm. It is made of 7052 hard glass, chosen because its coefficient of expansion matches that of a Kovar sleeve inserted into the outer jacket. The center tube is sealed at one end and terminates at the other end in a graded seal. A cut in the center tube opens

Glass valve with a cut central tube and Kovar sleeve.

A NEW CLARE RELAY...

the Type "R" combines extremely small size with unusual sensitivity and long life

Approximately Actual Size



SPECIFICATIONS

SIZE
Length: 1 7/16" — Height: 1 3/64" — Width: 1"

WEIGHT
Approximately 2 ounces

COIL
Single or double-wound

OPERATING VOLTAGE
Up to 230 volts d-c

ARMATURE
Single or double arm

CONTACT ASSEMBLY
Form A to C. Maximum of 10 springs in each pileup.

MOUNTING
Two #4-40 tapped holes in end of heelpiece

● This new CLARE Type "R" d-c Relay embodies many features of the famous CLARE Type "K" Relay, which was the first to combine the advantages of a telephone-type relay with the small size, light weight and resistance to vibration required to meet the rigid demands of aircraft service.

In appearance, the Type "R" resembles the Type "K", but, through hardly noticeable structural differences, CLARE has given the new Type "R" even greater sensitivity and operating range. Both relays use the same contact springs, but the Type "R" coil is longer and of larger diameter, to provide greater winding space. Life expectancy of the new relay has been not only increased but multiplied.

The CLARE Type "R" Relay retains in an improved form the reed armature suspension which discerning engineers have come to recognize as one of the subtler reasons for the superior performance of CLARE Type "K" Relays over other relays of comparable size and somewhat similar appearance.

The Type "R" is available as either an open or hermetically sealed relay. Clare sales engineers are located in principal cities to give you firsthand information on this new relay and to cooperate with you on any complex relay problem. Call them or write to C. P. Clare & Co., 4719 West Sunnyside Avenue, Chicago 30, Illinois. In Canada: Canadian Line Materials Ltd., Toronto 13. Cable Address: CLARELAY.

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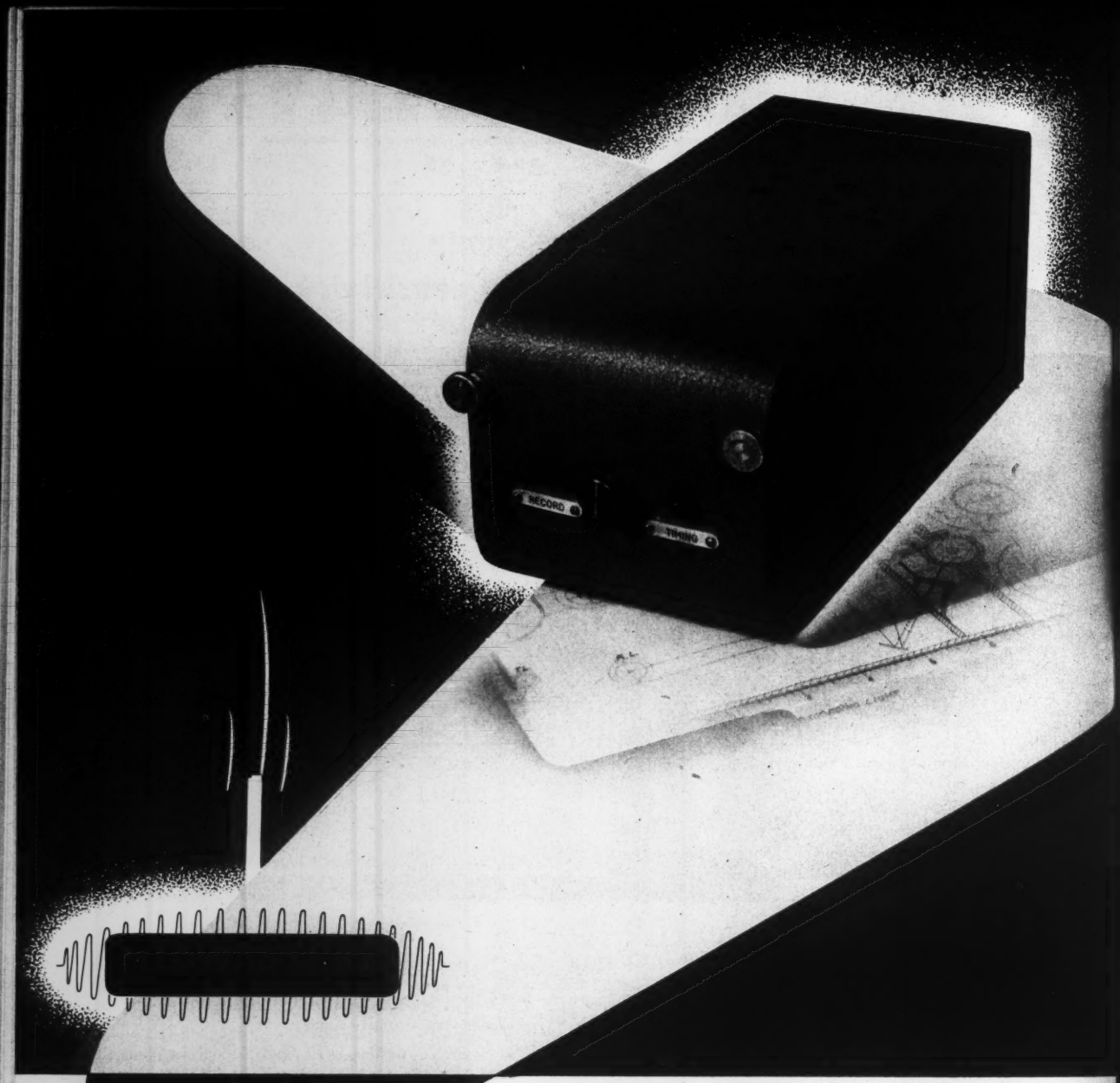

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Rugged simplicity and small size with excellent recording performance are the features of this new instrument designed to save space and weight, and to operate under the most severe conditions.

Some of the revealing specifications: Size — 5½" x 6¼" x 12⅛"; Weight with 100' of 3⅝" recording paper — approx. 12 pounds; Controls — Light Intensity, Paper Speed and Timing Line Choice (100 or 10 lines/sec.) accessible by removing 100' foot magazine; Power required — standard, 24 volts DC, special, 110 volts AC; Timing — precision oscillator drives horizontal galvanometer timer; Operation-tested under accelerations of more than 25 G's (one direction), vibration tests from 5to 55 cps at 10 g's.

Slightly larger 6-inch paper-width models available. Smaller Model 555-A available for uses requiring only a 50' recording.

Eighteen Model 102, or 12 Model 106-SS galvanometers may be used with the above oscillographs giving a wide range of frequency, sensitivity and balance characteristics.

This instrument is proved in tests and in use. Write for more information relative to your required application.

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- LIGHTEST
- SMALLEST
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western's Galvanometer Model smaller and lighter than any ow offered to industry, but or superior in all mechani- lectrical details, including vity and balance. Readily to any type oscillograph, ilable in appropriate un- frequency steps from 100 o 3500 cps. Precision manu- ture and design have reduced the size of the 102: 4-trace—width ¾", wt 1 lb.; 18-trace—width 2⅝", wt 3 lb.; 36-trace—width 5", wt 6 lb.

As an indication of the efficiency of this new galvanometer, below are tabulated essential characteristics of two representative elements.

Type	Nominal Undamped Natural Frequency	Frequency Range Flat ±5% CPS	Undamped DC Sens. at 12" Opt. Arm Ma/In.	Nom. Bal. Displacement Per G*
102A	100	0-60	0.009	0.006"
2000	2000	0-1200	11.2	0.006"

* Special Balance at slight extra cost

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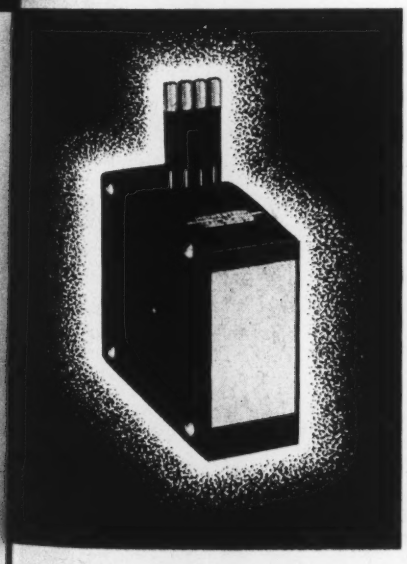
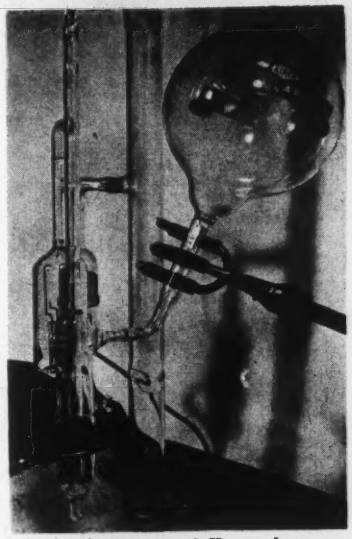




Induction heater around Kovar sleeve causes central tube to open and close cut.

and reseals as the outer tube is heated and cooled.

One of the properties of two optically polished surfaces is the enhancement of the intermolecular force which acts to hold the two surfaces in contact. Before incorporation into the system, the concentric tubes of the glass valve are carefully cut with a glass saw, and the surfaces are optically polished to a high degree of flatness. The ends are then placed in contact once again and are held in this position by the molecular force. A forepump is connected to the inner tube, and the unit is pumped to some convenient value of vacuum. With the external pressure and the intermolecular forces holding the cut sections together, the outer jacket (but not the inner tube) is glass-welded with a sharp flame. At this stage, there are two forces on the inner tube: the molecular adhesion and the external air pressure. During the cooling process, contraction adds another force. The total effect of these forces makes the seal vacuum-tight.

Under standard operating conditions, the inner tube is at the desired vacuum, and the space between the inner and outer tubes is approximately the same pressure as the gas to be admitted to the system. The Kovar sleeve is heated to a temperature of about 200 C. by an induction heater, which uses a single-turn coil, and heat flows from the Kovar into adjacent parts of the outer glass jacket. The over-all expansion of the outer tube exerts a force which opens the cut in the inner tube. When the desired quantity of gas has entered the system, the induction heater is turned off, and the resulting contraction of the outer jacket once again seals the system.

In operations requiring the admission of special gases to the system, a gas bottle is sealed to the sidearm. Several variations of this particular design and use of the glass valve are possible. Instead of the Kovar sleeve inserted into the outer jacket, the unit can be made entirely of pyrex, and the heat necessary to cause an expansion supplied by an external heater.

Tests have shown that this valve makes possible a continuously variable control of the rate at which gas can be admitted to an evacuated system. Complete data are not yet available for establishing a lower limit for use as an adjustable leak.

Color Yardstick Measures Microinches

SCHENECTADY, N. Y.—A new kind of "yardstick," which uses different colors to measure millionth-of-an-inch thicknesses, was described recently in Cleveland by one of America's foremost woman scientists.

Speaking at the 119th national meeting of the American Chemical Society, Dr. Katharine B. Blodgett, of the General Electric Research Laboratory at Schenectady, N. Y., called the new tool a "stepgage," and said it is used to measure thicknesses of extremely-thin films. A common example of such films is an ordinary soap bubble that reflects iridescent colors.

According to Dr. Blodgett, the stepgage is used like a yardstick, but in place of linear divisions are blocks of different colors, each of which, like the steps of a staircase, is higher than the one next to it. These blocks of color are mounted on a length of glass in the shape of a measuring rule.

In films a few millionths of an inch thick, colors vary with changes in thickness, so that a particular color indicates a particular thickness.

In using the stepgage, the color of a film of unknown thickness is matched to that block of color on the stepgage which is the same or similar. A thickness reading, marked underneath that particular block of color on the stepgage, indicates the thickness of the unknown film.

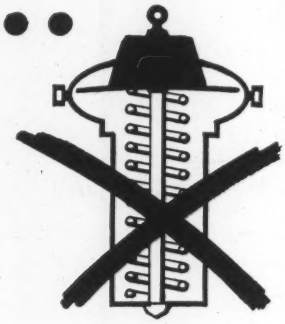
Color blocks on the stepgage she demonstrated at the meeting run from one-millionth-of-an-inch thick to 30 millionths, although gages with wider ranges can be made.

Explaining the process for making the gages, Dr. Blodgett said that a solution of stearic acid is first spread over a surface of water containing barium, this solution spontaneously spreading out so finely that it is only one layer of molecules thick.

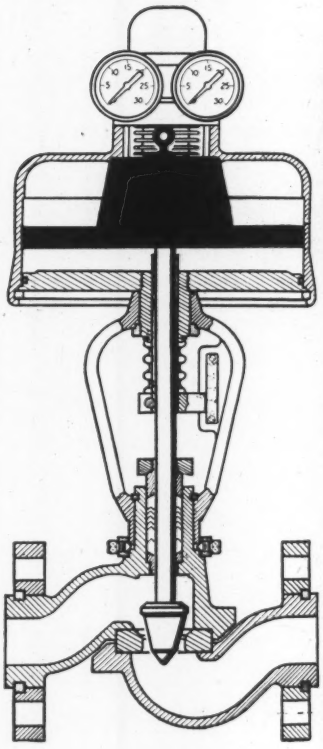
Then, by a dipping process, the glass plate is dipped in and out of the solution. Each coating represents a thickness of one layer of molecules. Ten such coatings applied result in a film on the glass plate one-millionth-of-an-inch thick, which reflects one particular color. The process is repeated until the desired range of thicknesses and colors is obtained.

See page 692 for more "Instruments on the March"

Powerful Control Action...



DOESN'T FIGHT SPRINGS



UTILIZES ALL THE FORCE

• The ANNIN Domotor positively and precisely controls hard-to-handle fluids under all types of conditions. The valve plug is positioned in both directions by over one ton of force—all available power is used to positively position the single seated valve plug. Write today for complete information.

FEATURES:

- SINGLE SEATED CONSTRUCTION for positive tight shutoffs.
- MINIMUM PISTON DISPLACEMENT for maximum operating speed.
- UNLIMITED VALVE TRAVEL for more accurate control.
- POSITIVE ACTION BOTH WAYS assures dependable operation under all conditions.
- BUILT IN POSITIONER eliminates cumbersome external weight of conventional valves.
- UNLIMITED POWER—any amount obtainable by increasing operating pressure.
- LIGHT WEIGHT—Less than ½ the weight of conventional valves.

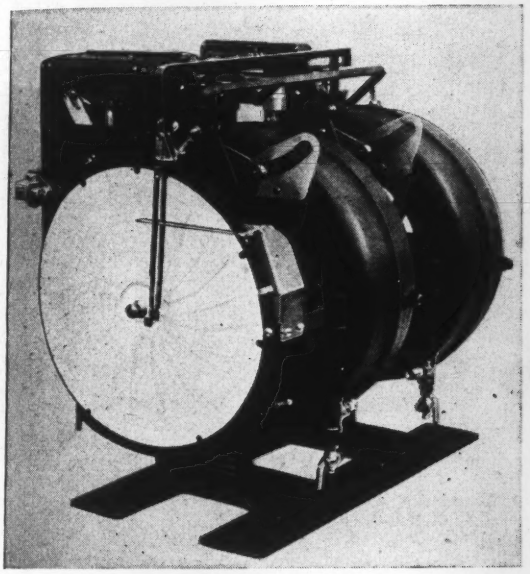
REMEMBER—Teflon Chevron packing has been standard equipment on all Annin Valves for over two years.

ANNIN DOMOTOR VALVES

THE ANNIN COMPANY 3500 Union Pacific Avenue, Los Angeles 23, California

5 reasons why industry likes

HAGAN RING BALANCE METERS



Typical Hagan Ring Balance Dual Flow Meter with two low pressure-low differential rings — for recording and integrating gas flow and recording air flow.

1 **THEY ARE SENSITIVE**—Torque is high, because rings have large cross-sectional area. Friction is low, because of knife edge suspension. The result is exceptionally high torque-to-friction ratio.

2 **THEY ARE ACCURATE**—Maximum rate of ring rotation occurs at low flow rates. Ample power to operate recording, integrating and other mechanisms is available over entire scale. High accuracy at low flows is especially advantageous where turndown range is wide.

3 **THEY ARE ADJUSTABLE**—Each ring assembly is adjustable for full scale differential over a range of 7 to 1. Rings are available for a continuous differential measuring range of ½ inch to 420 inches water column.

4 **THEY ARE SIMPLE**—There are no stuffing boxes or pressure tight bearings. No dampening devices are used. Level of mercury, or other sealing fluid, is not critical.

5 **THEY ARE RUGGED**—Design and materials produce precision results throughout a long life, requiring a minimum of personal attention, and costly maintenance.

For more detailed information on Hagan Ring Balance Meters, just fill out and mail the coupon or write to Hagan Corporation, Hagan Building, Pittsburgh 30, Pa.

HAGAN CORPORATION

RING BALANCE FLOW AND PRESSURE INSTRUMENTS
THRUSTORQ FORCE MEASURING DEVICES
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Please send me further information on Hagan Ring Balance Meters. I am particularly interested in.....

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COMPANY.....

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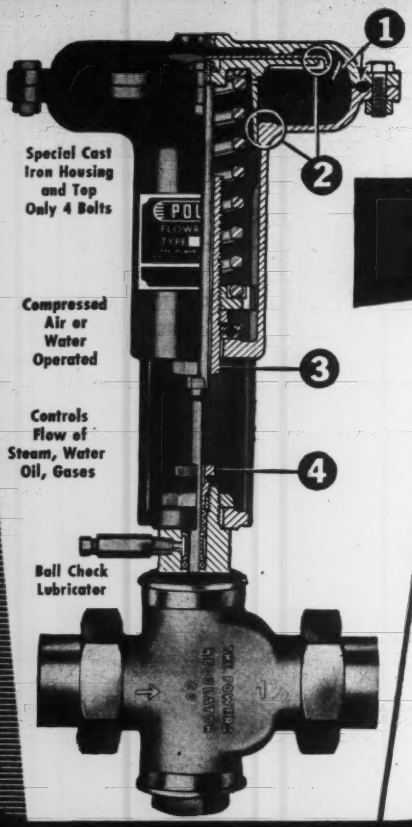
I -6



POWERS **LOWRITE** VALVE

★ **VE TOP**—Durable moulded neoprene diaphragm (1) has positive sealing bead which provides increased sealing action with increasing control pressure. Efficient diaphragm form insures ample and constant operating power thru full travel. Piston Plate Assembly (2) has a free floating thrust plate which absorbs side thrust. Closely guided piston plate maintains stem in accurate alignment.

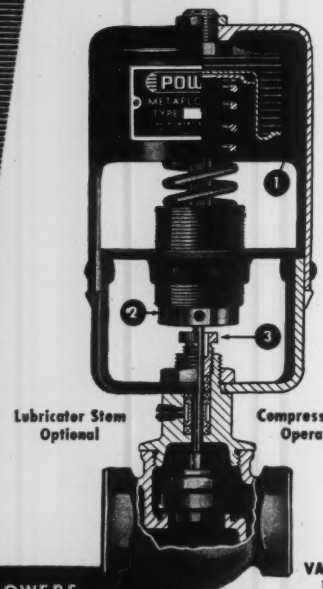
★ **ADJUSTING SCREW**—Ball bearing non-rising type. Easily accessible, 180° turning radius with starting pressure adjustable from 0 to 17 psi. Has enclosed rust proofed steel spring for full travel in 5 or 10 psi. control pressure change.

★ **BONNET ASSEMBLY**—Polished stainless steel stem in preformed lubricated metallic packing insures long life and low hysteresis.

VARIETY of VALVE BODIES — Sizes ½" thru 8" — For line pressures below 250 psi. Rugged construction to withstand piping strains. Single seat or double seat, bronze and stainless steel trim. Double unions and flanged ends. Available normally open (direct acting) or normally closed (reverse acting) and 3-way type valves.

POWERS BETTER Valve Tops

Packless Valves Available



POWERS **METAFLOW** VALVE

VALVE SIZES— ½" thru 2"
Bronze bodies, screwed ends. Rugged construction to withstand piping strains.

POWERS *Metaflow Valves* are small, sturdy, light-weight, reasonably priced, suitable for many control applications where the pressure differential does not exceed 75 lbs. per square inch.

1. HOUSING—High strength aluminum alloy. Hydraulically formed long life brass bellows provides smooth and powerful stroke.

2. ADJUSTING SCREW—Brass with rust proofed steel spring having 15 lbs. adjustment range to give proper sequence operation where required.

3. BONNET ASSEMBLY—Polished stainless steel stem in preformed lubricated metallic packing insures long life and low hysteresis.

TRIM—Composition disc with brass integral seat and self-aligning disc holder. Available normally open (direct acting) or normally closed (reverse acting), and 3-way.

METAFLOW NO-PAK VALVES prevent leakage of inflammable or harmful liquids or gases and provide vacuum protection. Are suitable for use with Freon, oil, gasoline, non-corrosive gases, hot or cold water and low pressure steam.

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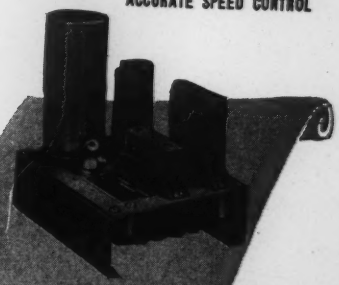
The controlling unit of these frequency standards is a bi-metallic fork, temperature-compensated and hermetically sealed against humidity and variations in barometric pressure. When combined with related equipment, accurate speed and time controls are afforded by mechanical, electrical, acoustical or optical means.

Instruments of our manufacture are used extensively by industry and government departments on such precision work as bomb sights and fire control.

Whatever your frequency problems may be, our engineers are ready to cooperate.

When requesting further details, please specify the Type Numbers on which information is desired.



TYPE 2001-2. BASIC UNIT
Frequencies, 200 to 1500 cycles. Dividers and Multipliers available for lower and higher frequencies. Miniaturized and JAN construction. Output, 6 volts.

TYPE 2005. UTILITY UNIT
consists of Type 2001-2 and booster to provide 10 watts at 110 V at 60 cyc. Input, 50-100 cyc.

TYPE 2121A. LAB. STANDARD
Outputs, 60 cycle, 0-110 Volts. 120-240 cycle impulses: Input, 50-400 cycles, 45 W.

TYPE 2111. POWER UNIT
50 W output. 0-110 V at 60 cyc. Input, 50-100 cyc., 275 W.

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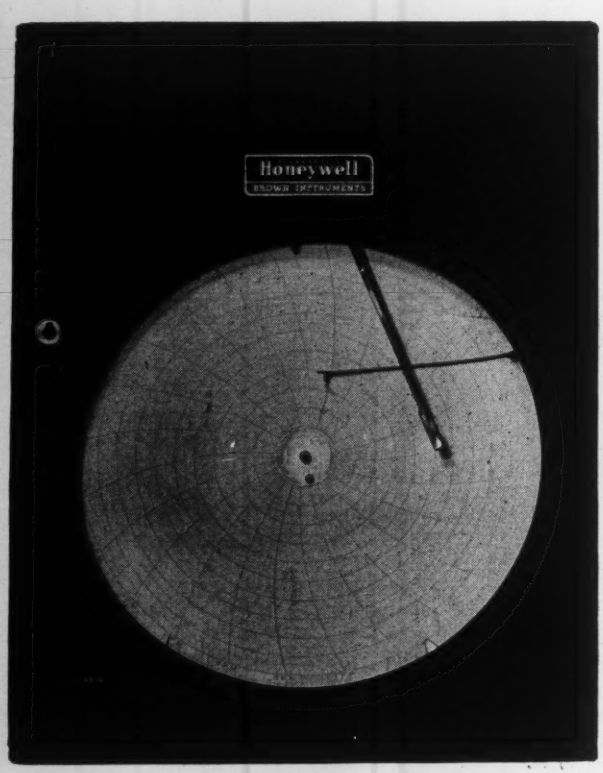
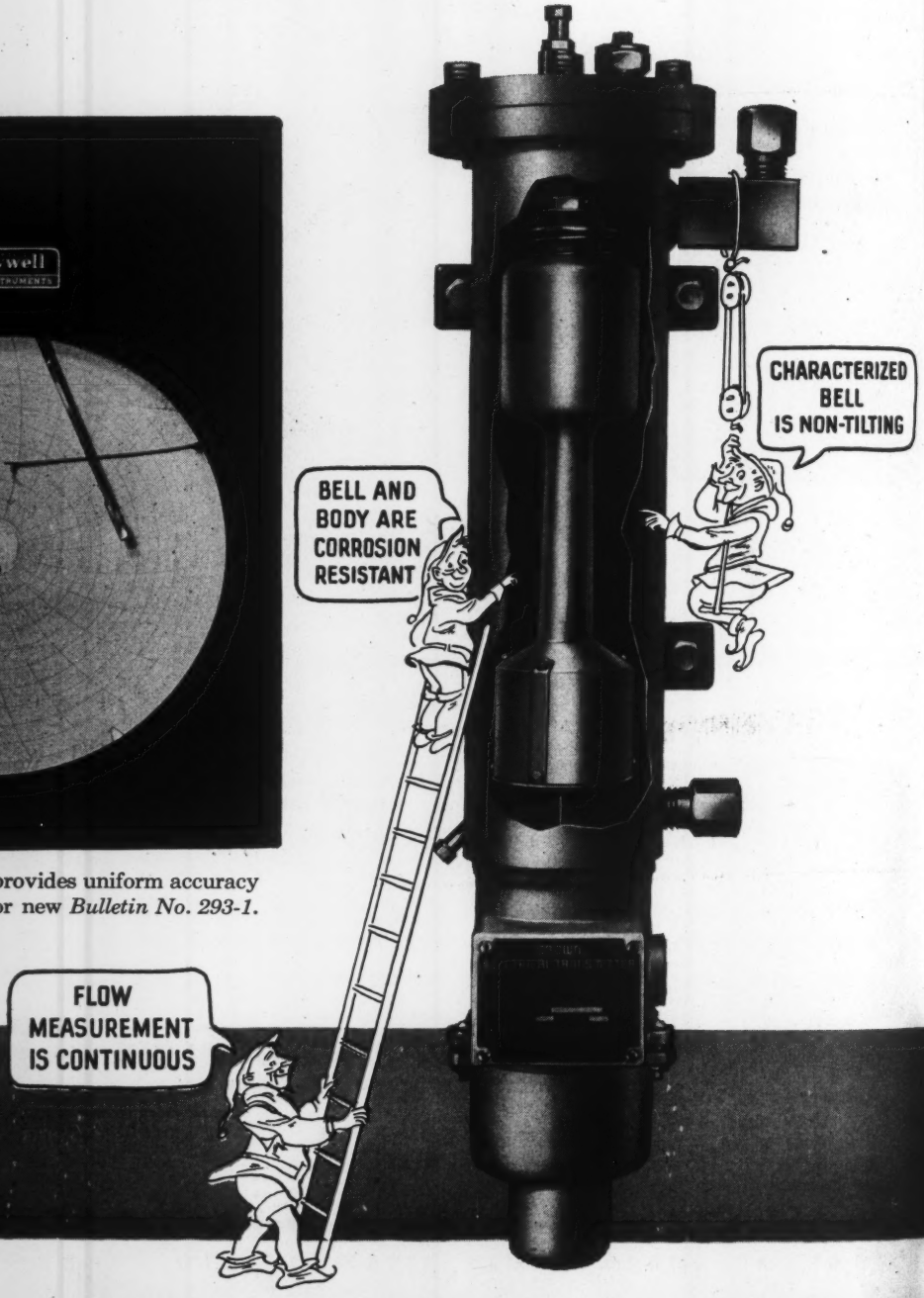
The New
Brown Electric Flow Meter

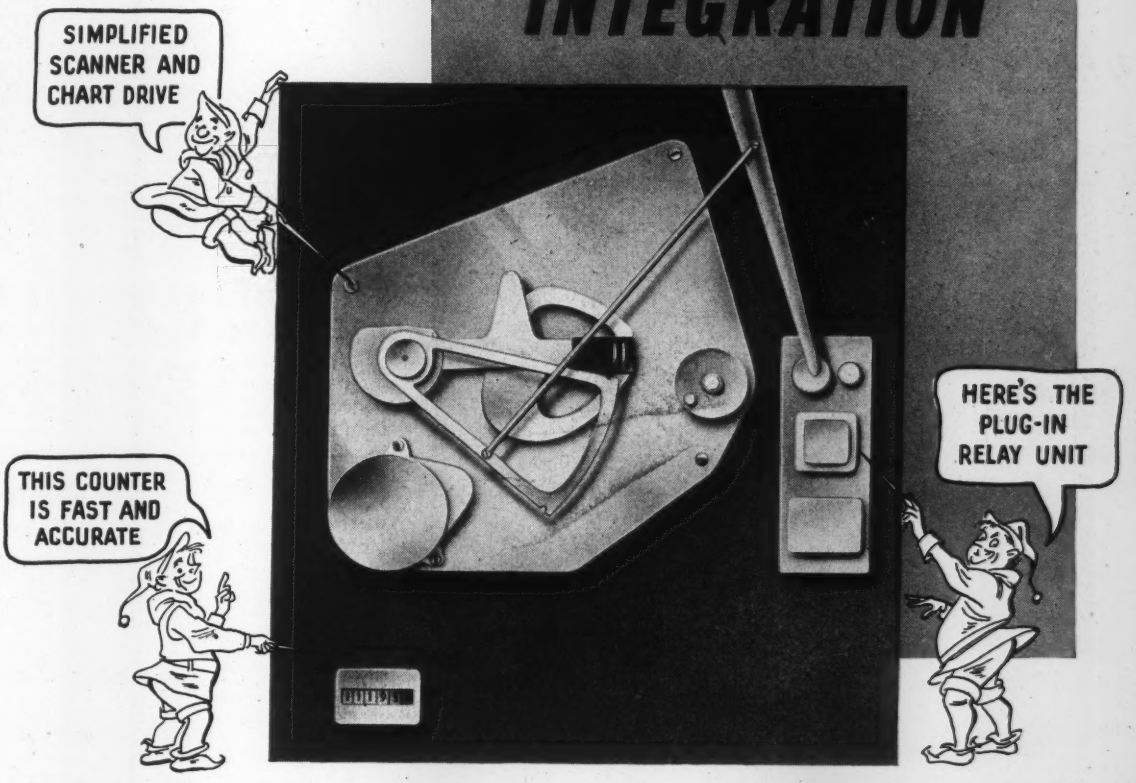


EVENLY-DIVIDED CHART . . . provides uniform accuracy for all rates of flow. Write for new *Bulletin No. 293-1.*



Flow Measurement and Accounting

incorporates . . . ELECTRONIC INTEGRATION



HERE'S another important advancement for power and process instrumentation . . . continuous flow measurement, with electronic integration! This Honeywell development eliminates intermittent measurement and slow, complicated totalizing . . . welcome news to process engineers and accountants.

The electronic integrator, consisting of but three major parts, simplifies accessibility and maintenance . . . permits quick checking and calibration. Scanning is rapid and extremely simple. The corrosion resistant meter body is of tubular construction, reducing weight and bulk. Transmission is electric, recorder is fast, chart is easily read under all conditions of flow. The characterized bell is corrosion resistant, too, and is specially designed to eliminate tilting.

Call in our local engineering representative for a discussion of your application.

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6 point Temperature Recorder

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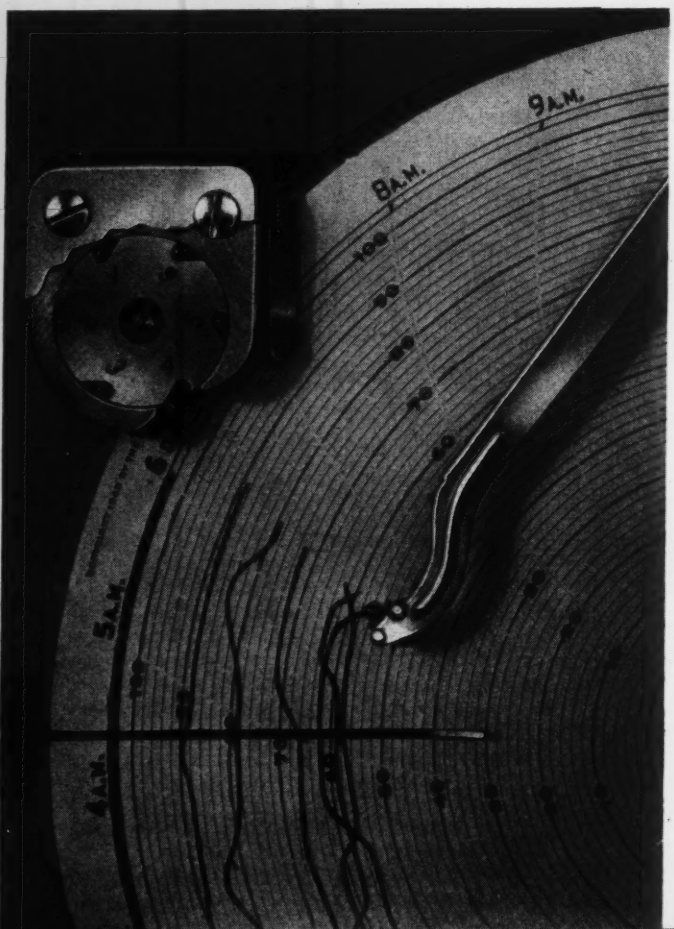

THE MULTI-RECORD DYNALOG*

By recording up-to-6 points in rapid succession, the Foxboro Multi-Record Dynalog gives the immediate warning of temperature drifts that you'd expect only from single-point recorders . . . all 6 records appear like unbroken lines! Check these outstanding features:

- **High speed recording—6 seconds between prints for maximum continuity of records**
- **Each record in a distinctive, non-smudging color**
- **Unique electronic circuit requires no standardizing, battery, galvanometer, or slide wire . . . gives STEPLESS continuous balancing**
- **Unmatched accuracy, lowest maintenance, greatest convenience**
- **Thermocouple and resistance-bulb types**
- **Uses convenient, low cost circular charts**

Get the *full* story. Write for Bulletin 427-1. **The Foxboro Company, 466 Neponset Avenue, Foxboro, Mass., U.S.A.**

*Reg. U. S. Pat. Off.

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1 GREATER STRENGTH than castings because extrusion eliminates porosity of metal.

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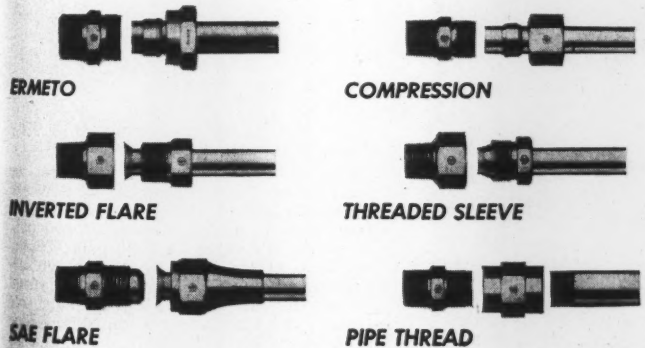
WRITE for helpful Weatherhead catalog F-1456 on Standard Fittings. Address: Dept. S, The Weatherhead Company, 300 East 131st Street, Cleveland 8, Ohio.



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Industrial Division • Cleveland 8, Ohio

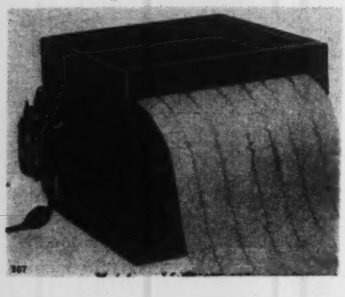
The Month's NEW INSTRUMENTS

In this department we report each month new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

FOR FURTHER INFORMATION USE THE POSTAGE-FREE ORDER CARD ON PAGE 721

High-speed Oscillograph

New "Dynograph" is direct-writing high-speed oscillograph. Features include pen-deflection linearity of 1 percent with pen response of 0.05 second;



sensitivity of 150 microvolts d-c. per centimeter of pen deflection; stability and drift-free operation through a special chopper-type amplifier; no extra equipment needed with reluctance-type pickups; true differential input obtained through special transformer coupling.—*Offner Electronics Inc.*, 5320 *North Kedzie Ave., Chicago, Ill.*

Mention No. 601 when filling out card.

Electrical Power Analyzer

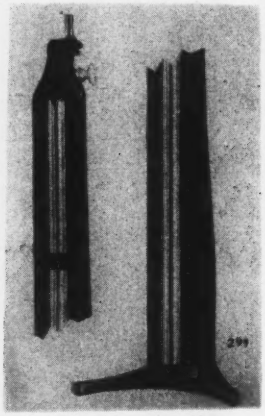
New "Model 188" analyzer provides means for measuring all factors in a power test, including 25-133 cps. 1-phase, 2-phase, and 3-phase voltage, current, power, and power factor. D-c. circuit measures insulation resistance in megohms and low resistances to fractions of an ohm. Use of polyphase cur-

rent transformer gives a-c. ammeter ranges of 1.5, 15, 50, 150, and 300 amp. Voltmeter ranges are 150, 300, and 600 v. Wattmeter ranges are 300 and 240,000 watts. Power factor indicated by use of monograph from value of reactive kva. Specifications include phase-rotation indicator, 1-percent accuracy of ammeter and voltmeter, 2-percent accuracy of wattmeter. Weight is 33 lbs.—*Niagara Electrical Instrument Co.*, 559 *Ellicott St., Buffalo* 3, *N. Y.*

Mention No. 602 when filling out card.

Absolute and Differential Manometer

New large-range manometer covers more than one-atmosphere pressure and provides absolute or differential manometric measurements. Designed with

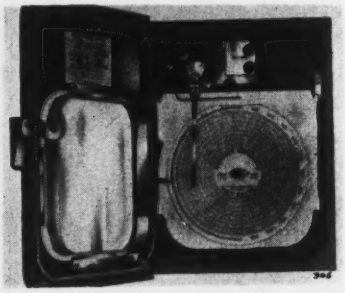


silk-screened scale on saran. Temperature coefficient of saran compensates exactly for changes in mercury density due to room-temperature variations. Other features include: metal rod to carry vernier, U cut-out on vernier-carrying block to eliminate parallax, rigid aluminum casting to support glass assembly.—*Emil Greiner Co.*, 20-26 *North Moore St., New York* 13, *N. Y.*

Mention No. 603 when filling out card.

Recording Voltmeters and Ammeters

New "Series-500 Electric Recorders" are recording voltmeters and ammeters. Instruments record voltage or current on 8-1 in. circular chart. New moving-

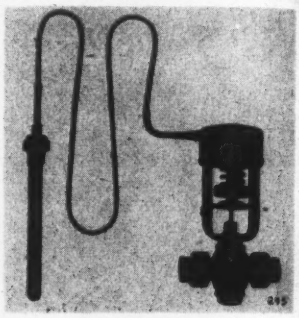


iron measuring mechanism has high actuating torque, shock-protected precision stainless-steel bearings, magnetic damping, and a locking device to prevent damage due to rough handling.—*The Bristol Co., Waterbury* 20, *Conn.*

Mention No. 604 when filling out card.

Temperature Regulator

New "No. 999" series of self-powered temperature regulators has press-formed frame of stainless steel, providing minimum heat conduction from

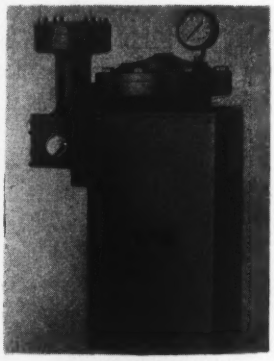


valve to regulator head, and assuring better control, less weight, and reduction in over-all dimensions. Large two-ply metal Sylphon bellows in thermal unit provides added power for valve operation and assures long service life. Temperature ranges from 40 F. to 440 F. Available in valve sizes 0.5 to 4 in.—*Robertshaw-Fulton Controls Co., Knoxville, Tenn.*

Mention No. 605 when filling out card.

Flow Signal Transmitter

New high-pressure flow transmitter is pneumatically-operated flow-differential measuring unit which transmits proportional signals to remote recording, indicating, or control instruments. Measures flow differentials of liquids,



gases or vapors; static pressure; or liquid level. Interchangeable elements cover range of pressure differential from 5.5-in. water column to 100 psi., at static pressures to 1500 psig. Transmitter consists of an input differential-pressure measuring unit, force balanced by an output system. Balancing force results from action on escapement-type pilot valve following any unbalance of linkage forces. Pressure differential across orifice, flow nozzle, or other pri-

Heating Safety

Protects

Your Investment

The Alnor Pyrotac excess temperature cut-off offers you low-cost, automatic protection against damage due to excessive temperatures... safeguards your investment in heating equipment and materials in process.

Simple in operation, the Pyrotac constantly indicates temperature of the heated equipment and sounds an alarm and/or shuts down heater circuits at a safe temperature. It may also be used as the only control on a process that requires a shut-down upon reaching a final temperature. Automatic thermocouple break protection assures safety if thermocouple or extension wires should break or burn out.

Available in scale ranges from 0-600°F. to 0°-3000°F. and Centigrade equivalents.

An Alnor quality instrument of laboratory precision and husky construction; yet the price is only . . .

$85.00 ***far lower than ordinary instruments of this type.***

Ask your Alnor Representative for complete details or write for bulletin that contains full description and wiring diagrams that show actual applications.

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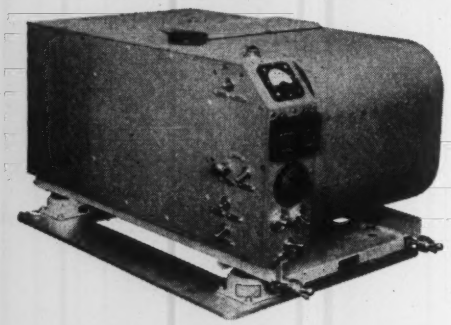
FOR VIBRATION, TEMPERATURE, STRESS, STRAIN ANALYSIS



MODEL 408 OSCILLOGRAPH

The Century Model 408 recording oscillograph was designed expressly for airborne and mobile operation. As with all Century products, this oscillograph incorporates the utmost in design and workmanship, along with improved features, yet it remains simple in its operation and maintenance.

FEATURES:

Size: 20" long, 12½" wide, 8⅞" high.

Weight: 60 pounds.

Number of Recording Channels: 6 to 50.

Detachable daylight loading magazine accommodating a roll of paper or film 8" x 200'.

Friction roller type paper drive by governor controlled electric motor with separate motor for takeup drive.

Paper speeds continuously and instantly variable without changing gears or sprockets.

Separate optical system for viewing before or during recording.

Glow tube timing system photographing .01 second and .1 second lines. .01 second lines instantly removable by toggle switch for slower speeds.

Data numbering at beginning of record.

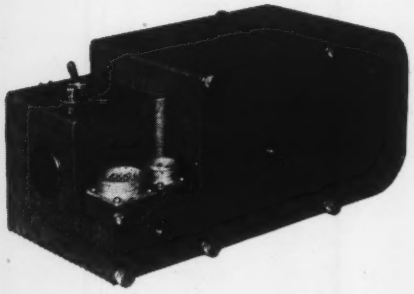
Footage indicator showing amount of paper remaining in magazine.

Automatic record length control.

Trace identification.

Remote control unit.

MODEL 409 OSCILLOGRAPH



The Century Model 409 oscillograph has been designed for recording data where space and weight requirements are limited. This oscillograph has been tested to record faithfully while subjected to accelerations up to 20 G's.

FEATURES:

Size: 5" x 5" x 11".

Weight: 11 pounds.

Cast Aluminum case.

Paper speeds variable ½" to 12" per second.

Detachable daylight loading magazine with a capacity of 3⅝" x 50' paper or film.

2 to 12 individual channels.

Trace identification.

Trace viewing.

For Complete Information Write 1340 North Utica

Century GEOPHYSICAL CORPORATION
TULSA, OKLAHOMA

1505 Race Street
Philadelphia, Pa.

EXPORT OFFICE:
149 Broadway, New York

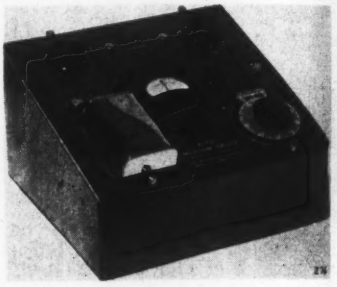
NEW INSTRUMENTS

mary device is connected to measuring element and is balanced by the force produced by modulated air pressure transmitted from pilot valve to balancing diaphragm. Output loading pressure has maximum value of 30 or 60 psig. Inertia of force-balance system is negligible. Transmitter has no pressure-type bearings, no stuffing boxes, and no manometric sealing fluid. Accuracy of measurement is within one percent of full-scale reading.—*Hagan Corp., Hagan Bldg., Pittsburgh 22, Penna.*

Mention No. 606 when filling out card.

Megohm Bridge

New "Model 144" megohm bridge is Wheatstone bridge on which resistances of ten megohms to one hundred million megohms (10^{14} ohms) may be read di-



rectly. Accuracy is one tenth of one percent over most of range. Unique circuit permits instrument to be calibrated against set of standard resistors calibrated by the National Bureau of Standards. Operates from batteries.—*Special Instruments Laboratory, Inc., 1003 Highland Ave., Knoxville, Tenn.*

Mention No. 607 when filling out card.

Volt-ohm-milliammeter

New battery-operated volt-ohm-milliammeter has 5-in. lucite meter case and input impedance of 20,000 ohms per volt d.c., 5,000 ohms per volt a.c.

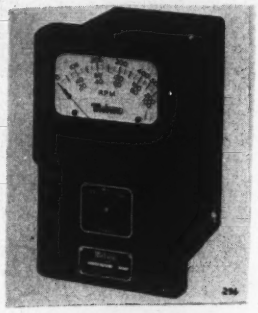
Ranges include: volts a.c. and d.c.—2.5, 10, 50, 250, 1,000, 5,000; milliamperes, d.c.—2.5, 10, 50, 250, 1,000; microamperes, d.c.—0 to 50; amperes, d.c.—0 to 10; decibels— −30 to +50 in 5 ranges; ohms—0 to 1,000, 10,000, 1 meg., 100 meg.—*Hickok Electrical Instrument Co., 10519 Dupont Ave., Cleveland 8, Ohio.*

Mention No. 608 when filling out card.

NEW INSTRUMENTS

Tachometer Indicator

New "Series 42P" tachometer indicator can be used with any Metron tachometer head. Three speed ranges measure speed over total range of 50



to 1. Scales are 4-in. long with 100 divisions. Calibration is easily adjustable in the field. With ordinary open wires, indicator can be located to 1,000 feet from head without affecting calibration. Selection of wrong range does not damage indicator.—*Metron Instrument Co., 432 Lincoln St., Denver 9, Colo.*

Mention No. 609 when filling out card.

Hook-on Power-factor Tester

New "Type AK-3" power-factor tester permits direct measurement of power factor without cutting conductors or interrupting service. May be used on any balanced 3-phase circuit. Gives direct power-factor readings in circuits

with voltages from 100 to 600 v. and currents from 15 to 600 amp. User clips voltage leads to potential source, clamps hook around conductor, and rotates dial to obtain power-factor reading. Readings accurate to 0.05 power factor. Frequency range is 50 to 90 cycles. Effective scale length is 13.5 in.—*General Electric Co., Schenectady 5, N. Y.*

Mention No. 610 when filling out card.

Ultrasonic Generator

New "Model 800" generator contains vacuum-tube oscillator which develops from 0 to 500 watts at 450 to 2000 kc. Power is fed to crystal transducer in aluminum vessel, which has same resonant frequency as oscillator. Liquids put in transducer are subjected to ul-

HELICOID
Chemical Gage

Standard dials: 0-15, 30, 60, 100, 150, 200, 300, 400, 500, 600, 800, 1000, 1500, 2000, 3000. Also 0-30" vac., 15 and vac., 30 and vac., 60 and vac.

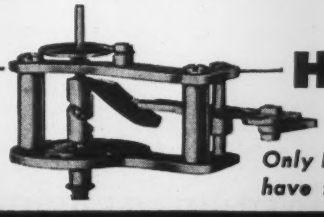
Supplied with Cartridge Snubber in socket for pump service.

Bronze
Cast Iron
Lead Coated Iron
Steel
Stainless Steel (316)
Monel
Hastelloy B
Hastelloy C
Dural (24 S-T)
Carpenter No. 20 (Duramet)
Nickel
Everdur
Hard Rubber

Here's a chemical gage for any pressure to 3,000 p.s.i. and also for vacuum or compound ranges, and temperatures to 300° F. Particularly suitable for chemicals and other viscous liquids that either corrode or clog a Bourdon tube gage.

One feature of this Chemical Gage is that the diaphragm is made of **"TEFLON"** which is flexible and resists practically all corrosive chemicals. No fragile metal foils are used. The diaphragm chamber is supplied of any metal most suitable for the service.

Available in the following dial sizes: 4½", 6", or 8½". 1" female N.P.T. bottom connection. Flanged connection also supplied.



HELICOID

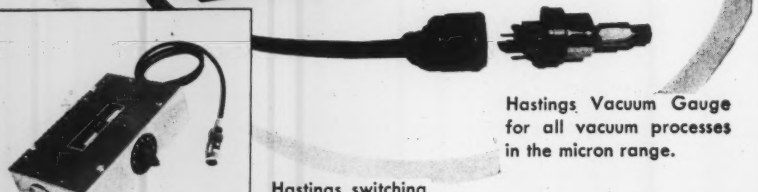
Only Helicoid Pressure Gages have the Helicoid Movement

ACCO

HELICOID GAGE DIVISION
AMERICAN CHAIN & CABLE COMPANY, INC.
Bridgeport 2, Connecticut

TRADE MARK

For Keeping Tabs On Nothing!



Hastings Vacuum Gauge for all vacuum processes in the micron range.

Hastings switching unit supplied with up to five gauge tubes.

The new Hastings direct-reading Vacuum Gauge gives rapid response (less than ½ second) for laboratory or production instrumentation. Its *unique* design features noble-metal thermopiles, and the nickel-plated tube prevents outgassing—will not contaminate the system. With the switching attachment, illustrated above, as many as five stations per standard selector unit may be connected to each indicator. Matched gauge tubes eliminate the need for additional adjustments when switching. The calibration of the gauge tube is not affected by exposure to atmospheric pressure or temperature so there is no need to reset the current each time the pressure changes. The accuracy and quick response of the gauge make it ideally suited for leak detection, warning work, or pressure-operated control systems. Vacuum Gauge Indicator Unit: $90. Gauge Tubes: $10 each. WRITE TODAY FOR DETAILED SPECIFICATION SHEET.

HASTINGS VACUUM GAUGE

CHARACTERISTICS

RANGE:
1-1000 microns Hg.

RESPONSE:
Time constant, less than ½ second.

VACUUM COUPLING:
Standard ⅛" IPS male thread.

POWER:
Voltage: 90-135 volts a-c; 50-60 cycle (can be used from 30 to 800 cps.)
Current: 0.01 amperes.
Wattage: 1 watt.

DIMENSIONS:
Indicator: 4¼" x 4½" x 7½"; weight, 48 ounces.
Gauge Tube: Maximum Outside Diameter 1 9/32". Over-all Length, including pins and nipple, 2¾". Internal volume less than ½ cu. in. Weight, less than 2 oz. Connected to Indicator by 6-foot cable terminating in an 8-prong octal socket.

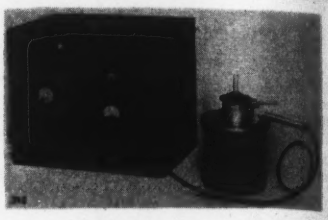
POWER CABLE:
6-foot terminating in standard 115-v plug.

HASTINGS INSTRUMENT COMPANY, INC.

HAMPTON, 5, VIRGINIA

DESIGNERS AND BUILDERS OF RAYDIST AND SPECIAL ELECTRONIC, ELECTRICAL, AND MECHANICAL INSTRUMENTS

NEW INSTRUMENTS



trasonic vibrations of crystal. Coils of oscillator are plug-in type, permitting coupling to transducers of different frequencies. Crystals available at operating frequencies. Instrument has timer and is grounded to eliminate radiation. Cooling water can be circulated around liquids being treated. Can clean or degrease small parts.—*Ultrasonic Engineering Co., P. O. Box 46. Maywood, Ill.*

Mention No. 611 when filling out card.

Audio-frequency Standard

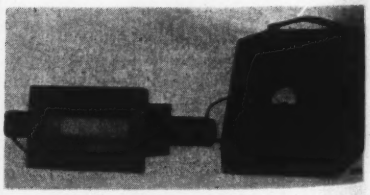
New instrument provides standard audio frequencies for checking speeds, tachometers, etc. Specifications include: Input power—45 watts at 115 v., 50 to 500 cycles; output frequencies—10, 20,

40, 60, 80, 100, 120, 140, 160, 180, and 190 cps.; output—45-v. negative non-linear saw-tooth to work into impedance of 250,000 ohms or more; accuracy—± 0.05 percent from –40 to 70 C., ± 0.02 percent in room-temperature range; weight—20 lbs.—*American Time Products, Inc., 580 Fifth Ave., New York 19, N. Y.*

Mention No. 612 when filling out card.

L-band Noise Source

New "Microwave Mega-node" provides random noise for L-BAND. Can be used for measurement of noise



figure, receiver gain, and calibration of standard signal source. Specifications are: Waveguide—RG-69/U, noise power output—(at 20C.)–15.84 db., frequency range—1200 to 1400 mc.—*Kay Electric Co., Pine Brook, N. J.*

Mention No. 613 when filling out card.

NEW INSTRUMENTS

Analog Computer

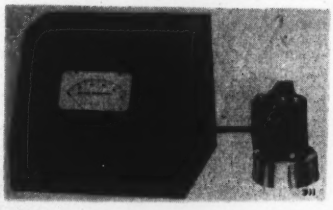
New electronic analog computer is nicknamed "Ida" for integro-differential analyzer. Solves linear differential equations with constant coefficients up to eighth order. Eight initial conditions may be set in problem. Auxiliary equipment extends usefulness to solution of differential equations of higher order than eight, differential equations with

non-constant coefficients and nonlinear differential equations. Solutions recorded in graphic form on two-channel oscillograph. Computed quantity can be viewed on oscilloscope. Problems are prepared on set-up board which automatically makes all necessary electrical connections. Problems can be changed in few seconds and can be stored on set-up boards for future use. Two control knobs apply forcing function and start and stop process. All 20 amplifiers are interchangeable plug-in units.—*Computer Corp. of America, 149 Church St., New York 7, N. Y.*

Mention No. 614 when filling out card.

Photometer

New photometer uses electron-multiplier tube as detector. Tube is mounted in small housing with rotary shutter of five apertures. Microammeter is in d-c. bridge-type two-stage stabilized



amplifier circuit. Photomultiplier tubes are interchangeable for spectral characteristics. Wide range of light intensities can be measured because of four steps of amplifier sensitivity and adjustable shutter openings. At highest sensitivity, light levels of 5/1,000,000 of a microlumen are measurable.—*Ultrasonic Engineering Co., P. O. Box 46, Maywood, Ill.*

Mention No. 615 when filling out card.

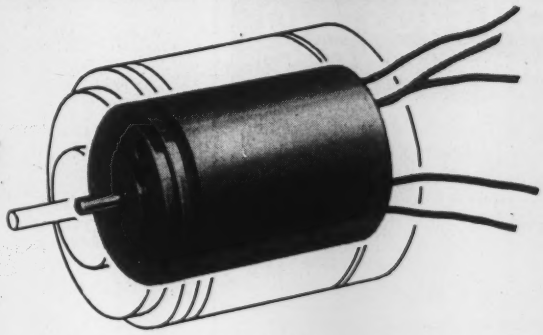
Metallograph

New "OPL" metallograph makes structural analysis of metal and other substances. Facilities for examination, study, and photographic reproduction

ECLIPSE-PIONEER

Announces the New Line of

PYGMY SYNCHROS



Size of pygmy as compared to AY-200 series outline

Eclipse-Pioneer has added a tiny new member to its great family of famous Autosyn* synchros. It's the new AY-500 series, a precision-built pygmy weighing only 1¾ oz. while scaling only 1.278″ long and .937″ in diameter (the same diameter, incidentally, as a twenty-five cent piece). Its accuracy and dependability are assured, thanks to Eclipse-Pioneer's 17 years of experience and leadership in the development of high precision synchros for aircraft, marine and industrial applications. For more detailed information on the AY-500 and other E-P Autosyns, such as the remarkably accurate AY-200 series (guaranteed accuracy to within 15 minutes on all production units), please write direct to Eclipse-Pioneer, Teterboro, N. J.

*REG. TRADE MARK BENDIX AVIATION CORPORATION

LOOK FOR THE PIONEER MARK OF QUALITY REG. U.S. PAT. OFF.

Typical Performance Characteristics

	One AY-201-3 Driving		One AY-500-3 Driving
	One AY-500-3 Control Transformer	Two AY-500-3 Control Transformer	One AY-500-3 Control Transformer
INPUT			
Voltage	26-volts, single-phase	26-volts, single-phase	26-volts, single-phase
Frequency	400 cycles	400 cycles	400 cycles
Current	88 milliamperes	110 milliamperes	55 milliamperes
Power	0.8 watts	1.2 watts	0.9 watts
Impedance	105+j280 ohms	100+j220 ohms	290+j370 ohms
OUTPUT			
Voltage Max. (rotor output)	17.9 volts	16.2 volts	14.1 volts
Voltage at null	40 millivolts	40 millivolts	40 millivolts
Sensitivity	310 millivolts/degree	280 millivolts/degree	245 millivolts/degree
Voltage phase shift	23 degrees	26 degrees	44 degrees
System accuracy (max. possible spread)	0.6 degrees	0.6 degrees	0.75 degrees

Other E-P precision components for servo mechanism and computing equipment:

Servo motors and systems • rate generators • gyros • stabilization equipment • turbine power supplies • remote indicating-transmitting systems and special purpose electron tubes.

For detailed information, write to Dept. A

ECLIPSE-PIONEER DIVISION of

TETERBORO, NEW JERSEY

Bendix AVIATION CORPORATION

Export Sales: Bendix International Division, 72 Fifth Avenue, New York 11, N. Y.

More Accurate Level Reading of LOW TEMPERATURE LIQUIDS . . .

JERGUSON

Large Chamber

NON-FROSTING* GAGES

YOU get the highest possible accuracy of reading on low temperature, low boiling point liquids with the patented Jerguson Non-Frosting Gage in the New Large Chamber model . . . because it insures less turbulence at the meniscus, and clear vision at the vision slot.

This new Jerguson model has 6 times larger area at the meniscus than the standard gage, so that there is a marked reduction in turbulence with light gaseous fluids that tend to boil or surge. Moreover, the problem of frosting encountered with these liquids has been eliminated by a patented frost preventing unit extending from the gage glass. This special transparent unit projects beyond the cover bolts and prevents frost from building up over the vision slot.

Here's a dual feature gage that assures greatly increased accuracy of reading for the process industries. If you have a problem with light gaseous fluids, or with gage frosting, it will pay you to investigate the new Jerguson Large Chamber Non-Frosting Gage . . . reflex or transparent.

Jerguson Large Chamber Gage, Transparent Type, with the patented Non-Frosting Gage Glass Extension. Write for literature on this gage, and on other non-frosting Jerguson models.

**Patented*

JERGUSON

Gages and Valves for the Observation of Liquids and Levels

JERGUSON GAGE & VALVE COMPANY

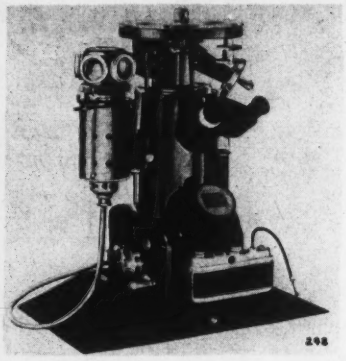
100 Fellsway, Somerville 45, Mass.

Representatives in Major Cities

Phone Listed Under JERGUSON

Jerguson Tress Gage & Valve Co. Ltd., London, Eng.

NEW INSTRUMENTS

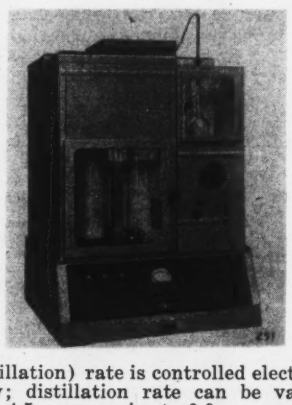


are provided. Staging table is lifted for lens changes. No refocusing necessary when lenses are changed. Technician observes sample through binoculars or on ground-glass screen without changing position. Photographs may be taken on 35-mm. film by swinging image from ground glass to camera. —*F. T. Griswold Mfg. Co., Wayne, Penna.*

Mention No. 616 when filling out card.

Automatic Distillation Apparatus

New distillation apparatus has following features: Temperature and volume are plotted continuously; time is recorded every two minutes; heating



(distillation) rate is controlled electronically; distillation rate can be varied from 4.5 cc per min. to 9.0 cc per min. After sample flask is in place, one adjustment obtains proper initial heat and distillation rate. Dimensions conform with standards specified by ASTM for distillation tests.—*Precision Scientific Co., 3737 W. Cortland St., Chicago 47, Ill.*

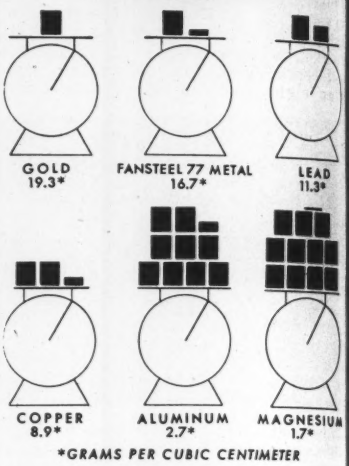
Mention No. 617 when filling out card.

Laboratory Oven

New forced-draft laboratory oven has multi-blade blower wheel and ballbearing motor. Uniformity of temperature and improved thermostat response are two features. Switch allows instant selection of low, medium, or high current input. Construction is stainless steel.—*Schaar and Co., 754 W. Lexington St., Chicago 7, Ill.*

Mention No. 618 when filling out card.

For High Density In Small Space



*GRAMS PER CUBIC CENTIMETER

Fansteel

77 Metal

Strong and machinable, with a density almost as high as gold and closely approaching that of pure tungsten, Fansteel 77 Metal is the practical, economical high density material.

Useful for rotors, flywheels, governors, balance weights where maximum weight is necessary in minimum space. Also useful for radiation shields against X-ray and gamma radiation.

Available forms include finished or semi-finished parts, bar, rod, rings, disks, slabs or special shapes. Fansteel Metallurgical Corporation, North Chicago, Illinois, U. S. A.

Ask for Bulletins:

- ☐ Fansteel 77 Metal
- ☐ Fansteel Siliconized Molybdenum
- ☐ Fansteel Tungsten and Molybdenum
- ☐ Fansteel Tantalum

12501-A

Fansteel

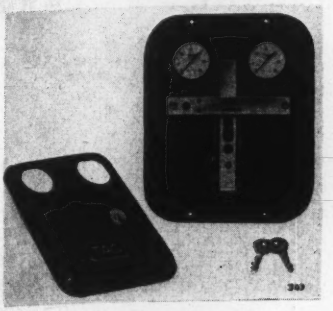
SPECIAL PRODUCTS

In Controlled Metallurgy

NEW INSTRUMENTS

Locked Controller

New "Model 8532" non-indicating controller for temperature and pressure has locked-in control-point settings, pre-

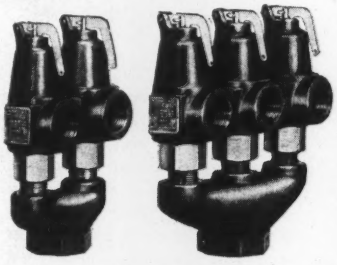


venting unauthorized persons from making unwanted changes.—*TAGliabue Instruments Div., Weston Electrical Instrument Corp., 614 Frelinghuysen Ave., Newark 5, N. J.*

Mention No. 619 when filling out card.

Multi-assembly Relief Valves

New assemblies consist of two or three "Series-33" safety-relief valves for guarding large water-heating boilers from excessive pressure. When

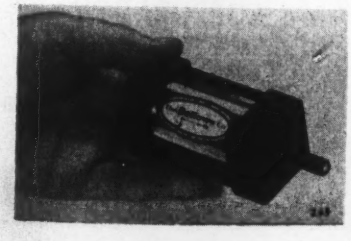


boiler pressure reaches 30 psi. only one valve opens to take care of normal thermal expansion. If "runaway" firing occurs, two or three valves open in succession, providing full rated discharge capacity of the assembly.—*McDonnell & Miller Inc., 3500 N. Spaulding Ave., Chicago 18, Ill.*

Mention No. 620 when filling out card.

Small Air Cylinder

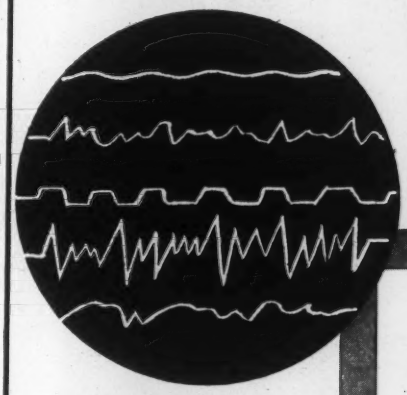
New "Han-D-Air" cylinder has 1.125-in. bore, 1-in. stroke, and spring return; develops thrust equal to applied pressure; has universal mounting and



SEE·MEASURE·RECORD

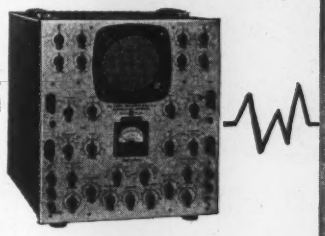
UP TO 10

transients at the same instant

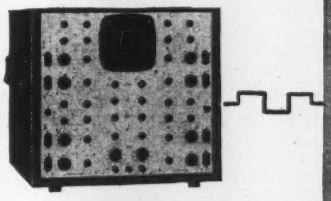


A signal from the brain and a man ducks, blinking his eyelashes. A huge bomber takes a load under various static and dynamic conditions and a multitude of strain lines take different characteristics. Electricity passes through electronic apparatus and emanates with different voltage, current, and phase relationships.

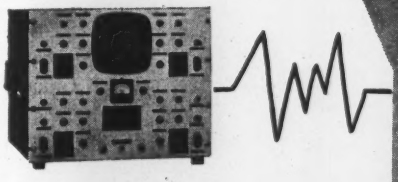
Observing simultaneous quantities like these—in testing, production, and research—proves the value of ETC multi-channel oscilloscopes every day. No other equipment can give you such correct time relationships for a number of simultaneous phenomena. No other equipment saves you the array of instruments and varying test procedure required by other means of coincident analysis. Write today and find out how you can save time, money, and trouble using ETC oscilloscopes, amplifiers, and tubes.



H-21 DUAL CHANNEL OSCILLOSCOPE. Sensitivity better than 0.085 Vdc/in. (30MV rms/in.)



H-45 FOUR CHANNEL OSCILLOSCOPE. Any combination of four DC or AC amplifiers, DC to 1 megacycle.



H-43 FOUR CHANNEL OSCILLOSCOPE. For recording through continuous strip cameras like the Fairchild Oscillo-Record F-246A

MULTI-GUN CATHODE RAY TUBES. 2, 4, 6, 8, and 10 gun tubes, potentiometer and radial deflection tubes.

ETC

electronic tube corporation

PHILADELPHIA 18, PENNSYLVANIA

NEW ONE-PACKAGE CONTROL SYSTEM

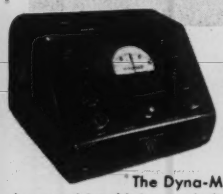
for

DIFFERENTIAL TRANSFORMERS

or

STRAIN GAGES

at the Flip of a Switch



DYNA-MYKE

The Dyna-Myke Model 129-B is a precision, high speed, dynamic micrometer using linear differential transformers as the sensing element. It measures and provides for recording such phenomena as force, torque, strain, vibration, acceleration, temperature, pressure, thickness, surface finish, etc., with a linear frequency response of DC to 1000 cps. Direct displacements are measured in five ranges from ±.1 inch to ±10 micro inches. On standard magnetic recorders a sensitivity of 1 micro inch per millimeter is available. A toggle switch converts the Dyna-Myke to a high frequency, high sensitivity strain gage indicator. The output is used to drive any type of magnetic, null balance or galvanometer recorder—or the DC or modulated carrier may be viewed on an Oscilloscope. Selsyn motors may be driven for remote indication or control. Request Technical Bulletin 129-B for full details.

DYNA-METER

The Dyna-Meter Model 144, when used with the Dyna-Myke, indicates by neon lights the peak amplitude of transients as fast as 1 millisecond. This indication may be instantaneous or a memory feature may be used to maintain the reading until reset. Built-in power relays provide on-or-off control to any plus or minus limits established by the Dyna-Myke. The combination of the Dyna-Myke and the Dyna-Meter offers many applications to industrial processes resulting in the elimination of scrap *at the source*. Uses in connection with machine tool operations are particularly impressive. Request Dyna-Meter Technical Bulletin 144.

Custom Builders of Electronic Instruments Since 1943

INDUSTRIAL ELECTRONICS, INCORPORATED

8064 Wheeler St., Detroit 10, Mich.

NEW INSTRUMENTS

threaded piston-rod. Cylinder is heavy-gauge brass; heads are aluminum alloy; piston cup is oil resistant.—*The Bellows Co., 222 W. Market St., Akron 9, Ohio.*

Mention No. 621 when filling out card.

Internal-inspection Borescope

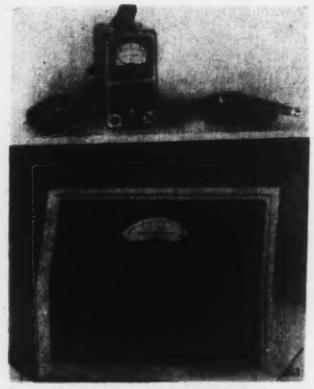
New optical borescope inspects inside walls of cylinders, gun barrels, etc. Optical system furnishes magnified and illuminated image of 30 degrees at right

angles to instrument access. Can be inserted in hole of 0.5-in. diameter to depth of one foot. Tube contains twelve corrected, achromatized fluoride-coated lenses. Furnished with 2-ft. electric cord.—*Testa Mfg. Co., 418 S. Pecan St., Los Angeles 33, Calif.*

Mention No. 622 when filling out card.

Radioactivity Counter

New count-rate instruments have accuracies of 2 and 5 percent. "Model 410," with an accuracy of 2 percent has standard Geiger probe input, and



can be used with alpha scintillation probe. A true Schmitt discriminator permits sine-wave, square-wave and pulse-counting without affecting calibration. "Model 409" is accurate to 5 percent, is small size 3.75 x 4.75 x 6.75 in.—*Atomic Instrument Co., 84 Massachusetts Ave., Cambridge 39, Mass.*

Mention No. 623 when filling out card.

Century

RECORDING GALVANOMETERS

The Century Model 210 Galvanometer has been designed and tested for the utmost in performance under any conditions. The unique small tubular type construction permits their installation in practically any type or make of photographic recording oscillographs. These galvanometers are offered at low cost over a wide range of frequencies and sensitivities to satisfy most recording requirements. For additional information, write for our Catalog No. CGC 206.

Manufactured under Century Pat. 2439576, also licensed by Kannestine Laboratories Patent 2149442.

Century

CENTURY GEOPHYSICAL CORPORATION

1340 North Utica

Tulsa, Oklahoma

EXPORT OFFICE: 149 Broadway, N. Y. — 1505 Race Street Philadelphia

World's Largest Manufacturer of Geophysical and Special Galvanometers

NEW INSTRUMENTS

Particle Detector-Amplifier

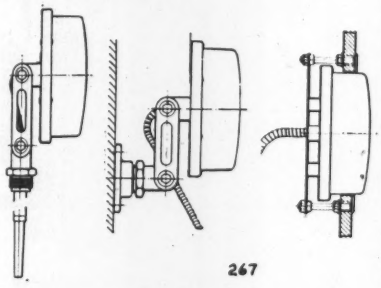
New flow detector-amplifier produces one voltage pulse of controlled width for each drop or particle that falls on probe. Ceramic stress-sensitive probe

is usable from minus 30 C. to plus 80 C., and from 5 to 95 percent relative humidity. Output can operate 1-ma. recorder or counter.—*Rochester Electronics Co., 662 Monroe Ave., Rochester 7, N. Y.*

Mention No. 624 when filling out card.

Adjustable-case Dial Thermometers

New adjustable-case mercury-actuated 4.5-in. dial thermometers have flush and panel-mounting models. Case is fully compensated for ambient temperatures; has heavy all-glass cover,



267

accuracy to one scale division. "Model 50-A" has rigid stem, tapered bulb, and adjustable case; "50-B" has wall mounting, flexible armor, and adjustable case; "50-C" has panel mounting and flexible armor.—*Palmer Thermometers Inc., 2501 Norwood Ave., Cincinnati 12, Ohio.*

Mention No. 625 when filling out card.

Flying-spot C-r Tube

New "5ZP16" 5-in. cathode-ray tube for flying-spot scanner in video-signal generator has resolution capability of better than 1000 lines at center of reproduced picture. Uses new "P16" metal-backed phosphor for short persistence, stable decay, and freedom from grain.—*Tube Dep't, Radio Corp. of America, Harrison, N. J.*

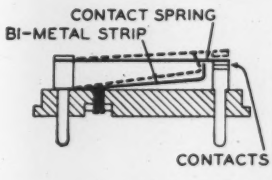
Mention No. 626 when filling out card.

CHACE BIMETAL
Keeps Them Home on the Range!

Stevens Type "C" Thermostat (shown full size) Manufactured by Stevens Mfg. Co. Mansfield, Ohio (Patent applied for)

TELEVISION plays a big part in keeping the "small fry" at home these days, and this Stevens Type C thermostat helps keep their favorite programs on the video screen. Actuated by Chace Thermostatic Bimetal, the thermostat is used in communications equipment, electronic devices and other apparatus requiring a high degree of temperature stability.

In its television and radio application this thermostat maintains a constant ambient temperature around the quartz crystals which control transmitter frequencies; this prevents variation in these frequencies. Since it is essential that the thermostat respond only to the temperature of the device it controls, an *electrically independent* strip of Chace Thermostatic Bimetal forms the actuating element. Current flows through the stainless steel or alloy spring, but does not pass through the thermostatic bimetal. As the bimetal element responds to a predetermined ambient temperature it overcomes the spring pressure and opens the contacts. This assures a sharp, clean break and eliminates artificial cycling or life-shortening "jitters."



The simplicity, efficiency and compactness possible when using Chace Thermostatic Bimetal enables Stevens to furnish this thermostat in a wide variety of production models, each using the same actuating element. Perhaps *your* product, too, can offer extra advantages when designed around an actuating element of this versatile material. Let The Chace Application Engineer, with his background and experience in the control of temperature-responsive devices by Chace Thermostatic Bimetal, help you.

IT BENDS WITH THE HEAT

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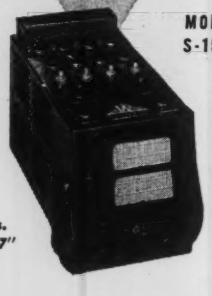
Thermostatic Bimetal
1609 BEARD AVE., DETROIT 9, MICH.

THE TWIN TUBE POCKETSCOPE®
BY WATERMAN

MODEL S-15-A



Wt. 16¼ lbs.
12" x 6" x 7"

A new concept in multiple trace oscilloscopy made possible by Waterman developed RAYONIC rectangular cathode ray tube, providing for the first time, optional screen characteristics in each channel. S-15-A is a portable twin tube, high sensitivity oscilloscope, with two independent vertical as well as horizontal channels. A "must" for investigation of electronic circuits in industry, school or laboratory.

Vertical channels: 10mv rms/inch, with response within —2DB from DC to 200kc, with pulse rise of 1.8μs. Horizontal channels: 1v rms/inch within —2DB from DC to 150kc, with pulse rise of 3μs. Non-frequency discriminating attenuators and gain controls, with internal calibration of traces. Repetitive or trigger time base, with linearization, from ½cps to 50kc, with ± sync. or trigger. Mu metal shield. Filter graph screen. And a host of other features.

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S-14-B WIDE BAND	POCKETSCOPE
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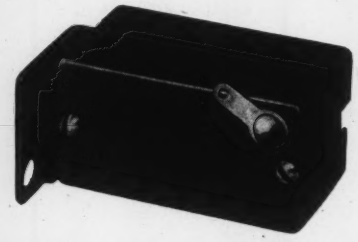
Also RAKSCOPES, LINEAR AMPLIFIERS, RAYONIC® TUBES and other equipment

WATERMAN PRODUCTS

NEW INSTRUMENTS

Dual Crystal Unit

New "Type DFS" unit has two separate quartz crystals entirely independent of another but so designed that frequency stability and zero adjustment



are equal on 100 and 1000 Kc. Both crystals can produce high oscillator output together with instant starting when used in conventional circuits. Calibration accuracy at 28 C. is ± 0.005 percent. Crystals are matched so that one trimmer may be used for both crystals. —*Valpey Crystal Corp., Holliston, Mass.*

Mention No. 627 when filling out card.

Small-parts Cleaner

New model cleaning machine features improved motor and drive shaft, as well as aluminum splash pens under

each of three glass jars. Universal motor is series-wound, rheostat-controlled, and can be reversed by toggle switch.—*L. and R. Manufacturing Co., 577 Elm St., Arlington, N. Y.*

Mention No. 628 when filling out card.

Shock Mounts

New mounting bases designed for airborne equipment are suitable for industrial installations. Load range is 6 to 80 lbs. Mounting base is carried by

four metallic spring-type isolators, which have high vibration-isolating efficiency. Friction dampening prevents excessive movement at reasonant frequencies.—*T. R. Finn & Co., Inc., 333 Jackson Ave., Bronx 54, N. Y.*

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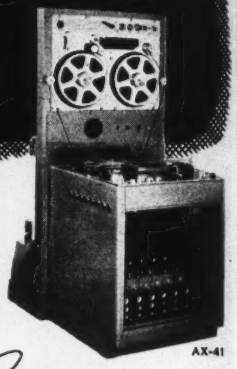
to 100,000 cps!



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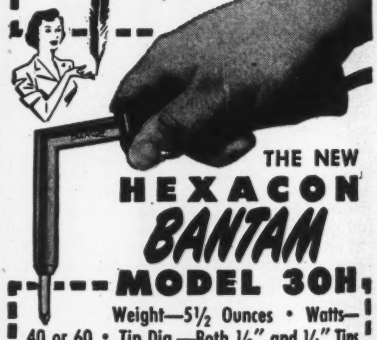

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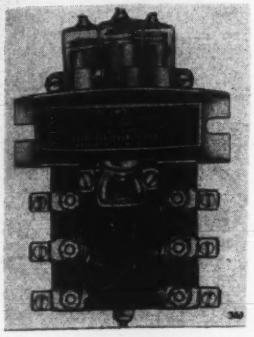
NEW INSTRUMENTS

Mercury-contact Plunger Relay

New "Type Em-7" relay is three-pole type employing one coil. Tungsten contacts are hermetically sealed in hydrogen-filled glass tubes. Three stand-

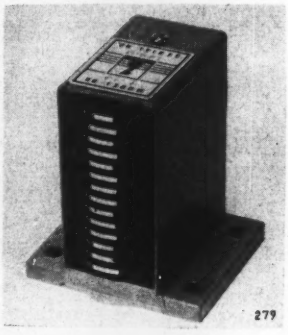


ard "Type-EMT" tubes are used in one coil structure to provide reliable and positive simultaneous contacts for loads up to 35 amp. at 115 v. a.c., or 25 amp. at 220 v. a.c. per contact.—*Ebert Electronics Co.*, 185-09 *Jamaica Ave.*, *Hollis 7, Long Island, N. Y.*

Mention No. 630 when filling out card.

Magnetic-tape Pickup

New "BK-1500 Series" multichannel magnetic record-reproduce head is available with 3 to 14 channels. Design features include balanced magnetic construction with gaps at front and rear.



Assembly is nonmicrophonic and impervious to moisture. Shields and pole pieces are grounded to housing. Maximum output level at 1000 cps. and 7.5 in. per sec. tape speed is 0.002 v. rms.—*Brush Development Co.*, 3405 *Perkins Ave.*, *Cleveland* 14, *Ohio.*

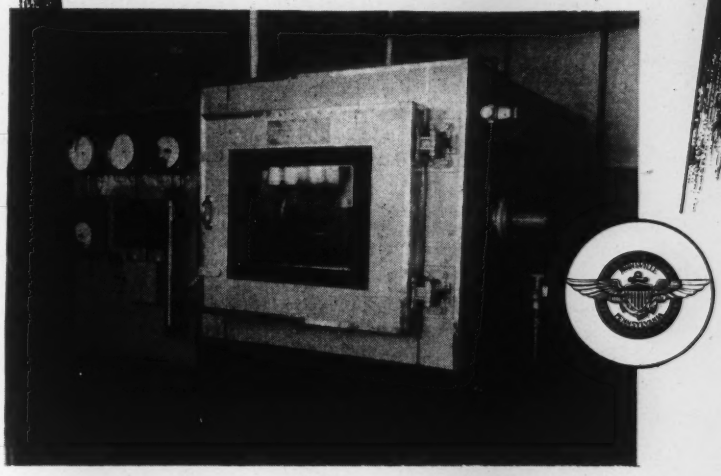
Mention No. 631 when filling out card.

Cathode-ray Tube

New "Type 5 YP-" cathode-ray tube has 1-in. vertical deflection for 12-volts peak applied to deflection plates, per kv. of anode-2 potential. Intensifier increases brightness and decreases spot size. Input capacitance to vertical-deflection plates is only 1.7 uuf.—*Instrument Div.*, *Allen B. DuMont Laboratories, Inc.*, 1000 *Main Ave.*, *Clifton, N. J.*

Mention No. 632 when filling out card.

U. S. NAVAL AIR DEVELOPMENT CENTER
JOHNSVILLE, PA.
takes its
ENVIRONMENTAL TEST PROBLEMS
to Tenney



Maximum *flexibility, efficiency, dependability*—those are essentials of test-chamber design for military research use. And those are the qualities engineered into the Tenney Test Chamber recently installed at the U. S. Naval Air Development Center, Johnsville, Pa., for environmental testing of aircraft components.

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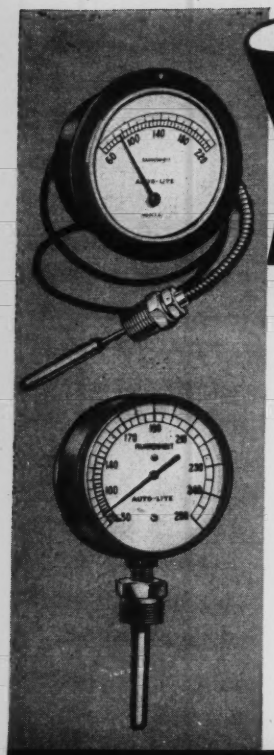

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Illustrated, at top: Model G Indicating Thermometer, flush mounting type with capillary tubing for remote reading. Priced from $18. At bottom: Model V Thermometer (vapor pressure type). Rigid stem for direct mounting. Priced from $10.25.

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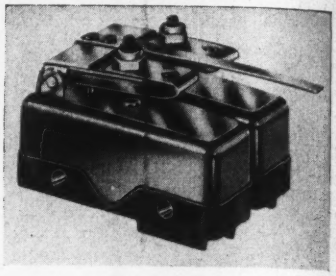
NEW INSTRUMENTS

Ganged Switches

New "Type SAT-I-ZI" ganged-switch assembly operates two snap-acting s-p. d-t. switches by single actuating mechanism. Operating point of each unit in

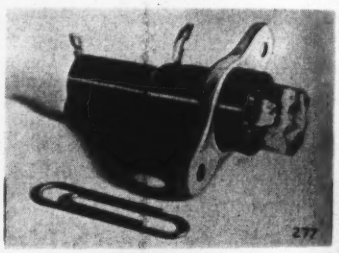


assembly can be set individually. Construction permits two, three, or four switches to be installed and set for simultaneous operation or for operation in special sequences.—*Unimax Switch Div., The W. L. Maxson Corp., 460 West 34th Street, New York 1, N. Y.*

Mention No. 633 when filling out card.

Indicator Fuseholder

New miniaturized indicating fuseholder instantly spots blown fuse. Has neon bulb and double contacts molded

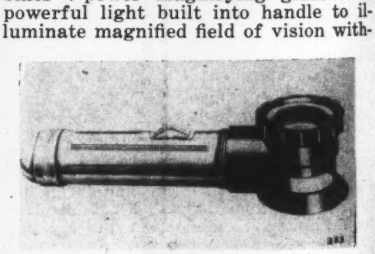


as integral part of lens. Neon bulb glows when fuse blows. Requires mounting centers and clearance behind panel of only 1.375 in.—*Alden Products Co., 117 North Main St., Brockton, 64, Mass.*

Mention No. 634 when filling out card.

Flashlight-Magnifier

New portable "Flash-O-Lens" combines 7-power magnifying glass with powerful light built into handle to illuminate magnified field of vision with-



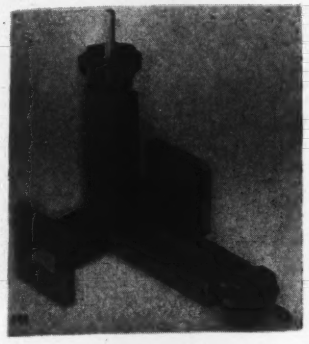
out throwing direct rays in user's eyes. Uses standard dry cells and new Bausch & Lomb lens system.—*Abbeon Supply Co., 58-10 41st Dr., Woodside, N. Y.*

Mention No. 635 when filling out card.

NEW INSTRUMENTS

Waveguide Tuner

New "880A" E-H tuner is a matching section for tuning out discontinuities in high-power systems or tuning systems where low leakage is essential. It is a hybrid waveguide "tee" with



movable contacting shorts placed in both shunt and series arms. Permits reduction of VSWR's as high as 20:1 to values less than 1.02. Designed for use in tuning out residual VSWR of loads, antennas, bolometer and crystal mounts. 6 waveguide sizes: 3 x 1.5 in., 2 x 1 in., 1.5 x 0.75 in., 1.25 x 0.625 in., 1 x 0.5 in., 0.702 x 0.391 in.—*Hewlett-Packard Co.*, 395 *Page Mill Rd., Palo Alto, Calif.*

Mention No. 636 when filling out card.

Waveguide Power Termination

New power-dissipating terminations are designed for dummy load for high-power transmitters. Consists of rectangular waveguide section containing high-loss material carefully tapered for

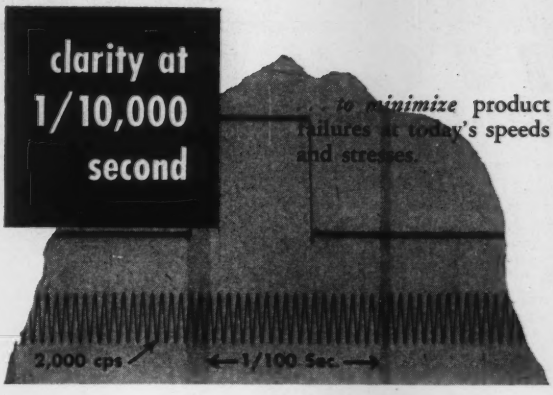
low VSWR. Cooling fins on waveguide dissipate power absorbed by unit. Models "912A" maximum VSWR 1.1, are offered in sizes 3 x 1.5 in. and 1 x 0.5 in.; models "910A" maximum VSWR 1.06, are offered in six sizes.—*Hewlett-Packard Co.*, 395 *Page Mill Rd., Palo Alto, Calif.*

Mention No. 637 when filling out card.

Servoamplifier

New "410-B" 60-cycle servoamplifier with 5-watt output is designed to drive servoloop motor. It features independent controls on gain, carrier phase-shift, and damping. Specifications include: max. gain, 1000; phase variable from +20 to −140 deg., internal pickup below 3 mv. rms. Companion power supplies and modulators available.—*Industrial Control Co.*, 1462 *Undercliff Ave., New York* 52, *N. Y.*

Mention No. 638 when filling out card.



A PERMANENT RECORD is vital in present-day testing, for the millisecond and microsecond have become significant time periods, and interpretation of a phenomenon measured in these units must be accomplished after the phenomenon itself has passed. Consolidated Recording Oscillographs, with record speeds of 100 inches-per-second and higher, stretch the time coordinate to enable the test engineer to read with ease such events and to measure them precisely for evaluation. Consolidated Galvanometers, with *linear* frequency response up to 2000 cycles-per-second and more, are employed in the oscillographs to take full advantage of the high record speeds and to yield records on which 0.0002 second may be read with the unaided eye.

The portion of oscillograph record shown was travelling at 100 inches-per-second, each of the vertical timing lines representing 1/100th of a second "stopped" for leisurely, searching analysis. The traces pictured are merely laboratory phenomena. They could as well be the high frequency vibrations and transient stresses which are so important a consideration in today's engineering designs. The test engineer's problem of isolating, measuring and interpreting these phenomena can be answered by Consolidated Recording Oscillographs and Galvanometers. Models are available to fit virtually every precision instrumentation program.

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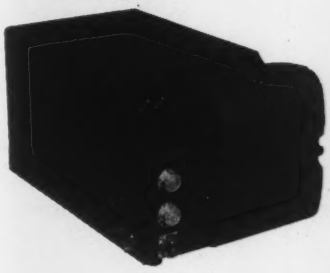
RECORDING OSCILLOGRAPHS

CEC's 5-114 Recording Oscillograph, recording up to 18 traces simultaneously on 7″-wide paper or film, is designed as the ultimate in precision, versatility, and operating convenience and incorporates many features available only through special accessories on many other oscillographs. Recording speeds from ½″ to 115″ per second and easily removable feed-and-takeup record magazines of 125, 250, and 600-ft. capacity offer an unusually wide application range. Write for Bulletin CEC-1500-X25.



CEC's 5-116 Recording Oscillograph, costing considerably less than other instruments comparable in precision and versatility, produces records equal in quality to those of the 5-114 and lacks only those features which may be dispensed with in many recording applications. Recording up to either 9 or 14 traces, the 5-116 employs 5″-wide paper or film at recording speeds of ¼″ to 100″ per second. Its removable feed-and-takeup magazine holds 125 feet of recording paper and is designed for the utmost loading and unloading convenience. Write for Bulletin CEC-1521-X8.

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MICROPOT

PRECISION TEN-TURN POTENTIOMETER

1. You get permanent accuracy because the resistance wire is locked in place, it is precision positioned and moulded integrally with the housing.
2. You get permanently accurate settings, smooth action and low uniform torque provided by the stainless steel, precision ground, double thread lead screw guiding the moving contact.
3. You get precise positioning of the moving contact because of the two bearings supporting the rotor assembly.
4. You get good rigid terminals because they are moulded integrally with the housing.
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Units for immediate shipment:
1,000 to 30,000 ohm range.
Special resistance values made to order.

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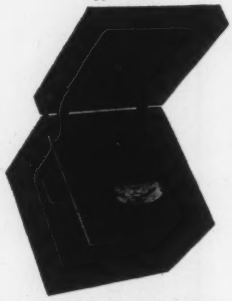
Type 518



Available ranges 100 volts to 35,000 volts

Measure true R.M.S. values on A.C., no waveform or frequency errors.

NO POWER CONSUMPTION

Leakage resistance greater than one million megohms. These meters may be used to measure

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NEW INSTRUMENTS

Precision VDR

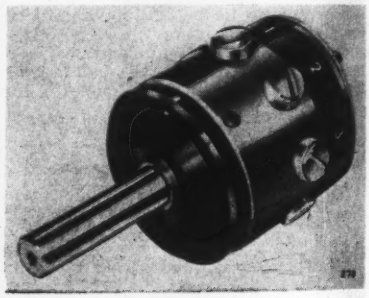
New "Type 746" precision voltage-dividing resistor has all-metal construction for close tolerances. Permits ganging to 20 units on single shaft, easy

replacement of units, and means of phasing each unit without disassembly. Special plug-in units available. Diameter is 1.75 in. Resistances up to 100,000 ohms. Accuracy of 0.5 percent linear and 1 percent nonlinear. Torque is 1.5 in.-oz.—*Fairchild Camera and Instrument Corp.*, 88-06 *Van Wyck Blvd., Jamaica, N. Y.*

Mention No. 639 when filling out card.

Small Low-torque VDR

New "Type 85129 Syncromount" voltage-dividing resistor has low-torque shaft mounted in ball bearings; has small size, 1.125-in. diam., and can be



furnished with linear or functional output. Total resistance to 100,000 ohms; torque less than 0.2 in.-oz.—*G. M. Giannini & Co.*, 285 *W. Colorado St., Pasadena* 1, *Calif.*

Mention No. 640 when filling out card.

Time-delay Flow-control Elements

New calibrated flow-control elements provide time delays in instrument operations. Elements are fabricated from porous stainless-steel filter material. Over-all dimensions are small—element having flow of 5 cc. of air per min. at 10-psi. differential fits into 1-in. long cylinder. Flows are calibrated at differential pressures equal to those used in instrument.—*Micro Metallic Corp.*, 30 *Sea Cliff Ave., Glen Cove, N. Y.*

Mention No. 641 when filling out card.

NEW INSTRUMENTS

Miniature VDR

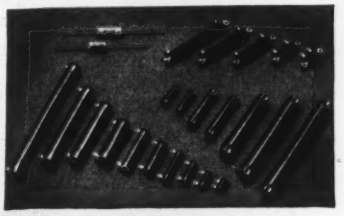
New "Tinytorque" miniature voltage-dividing resistor measures 0.875 in. in diam. and weighs 0.56 oz. Available in

resistances from 1,000 to 100,000 ohms in single section and ganged assemblies with single or double shaft extensions. Power rating is 0.5 watt.—*Helipot Corp., South Pasadena, Calif.*

Mention No. 642 when filling out card.

Wire-wound Rheostats

New "JAN-type" rheostats are offered in eleven models. Models include both standard and enclosed types, in sizes ranging from 25 to 750 watts. They

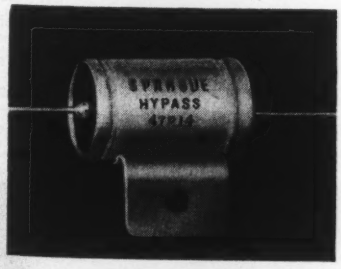


meet all tests prescribed by Specification JAN-R-22, including 5-hour vibration test, 50-hour salt spray corroson test, and 150-hour 95 percent humidity electrolysis test.—*Ohmite Mfg. Co.*, 4981 *Flournoy St., Chicago 44, Ill.*

Mention N. 643 when filling out card.

High-voltage Capacitor

New "Hypass" 1,000- and 2,500-volt d-c. three-terminal-network feed-thru capacitors are suited for suppression of



radio interference and harmonic generation in high-voltage circuits of transmitters and industrial electronic equipment.—*Sprague Electric Co., North Adams, Mass.*

Mention No. 644 when filling out card.

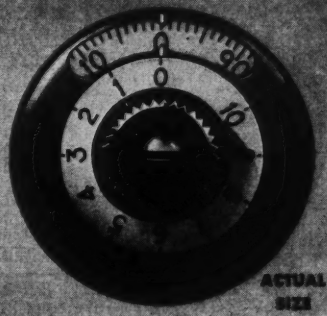
MICRODIAL
TEN TURN-COUNTING DIAL

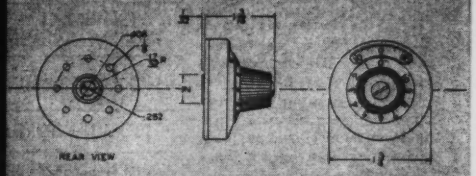
Microdial is composed of two concentrically mounted dials . . . one for counting increments of each turn and the other for counting turns. The incremental dial has 100 equal divisions and is attached rigidly to the shaft so there is no backlash. Thus the contact position is indicated to an indexed accuracy of 1 part in 1000. Rotation is continuous in either direction. There are no stops on the Microdial assembly.

COMPACT . . . Microdial has same O.D. as Micropot . . . requires no more panel space.

CLEAR READING . . . Forced fast-reading tests showed only 1/20th as many errors with Microdial open window as with next most legible dial. Turn counter distinguishes between 0 and 10 turn readings, and accelerates to avoid confusion on readings near integral turns. Precise readings are made from larger dial with maximum separation of graduations and wide angle visibility.

CONVENIENT . . . delivered completely assembled with dials synchronized. Easily mounted in a few seconds. All dials may be locked.





Microdial . . . turn-counting dial, primarily designed for use on Micropot ten turn linear potentiometers . . . use it on any multiturn device having ten turns or less.

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for measurements
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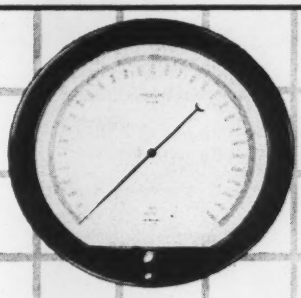
of extreme accuracy



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- √ Revolving dial zero adjustment
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- √ Special designs for use with mercury

For the unusual pressure gauge application — where extreme accuracy and stability under continuous use or other exacting conditions are essential — Heise Gauges can be specified with confidence.

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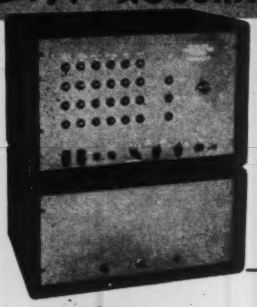

-using $f=\frac{n}{t}$

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MEGACYCLE
FREQUENCY-TIME
COUNTER

Model 801
by Potter

Now, the Potter Instrument Company offers all in one equipment, the features heretofore available only in separate counting systems. Two complete counting channels, a 100 kc crystal oscillator time base and unique gating circuits are combined to provide the new FREQUENCY-TIME COUNTER.

FREQUENCY MEASUREMENTS	0 to 1 mc range by counting cycles per pre-selected time or by measuring time per pre-selected count. Accuracy 0.001% minimum.
TIME INTERVAL MEASUREMENTS	0 to 10 seconds ± 10 microseconds.
FREQUENCY RATIO MEASUREMENTS	Ratio of two external frequencies can be measured.
SECONDARY FREQUENCY	100 kc crystal oscillator with divided frequencies available at 10, 1 kc and 100, 10, 1 cps.
TOTALIZING COUNTER	Six decades, pulses 0 to 1 mc, sine wave 10 cps to 1 mc.
DIRECT RPM READING TACHOMETER	Through the use of an external 60 count per revolution photoelectric disc generator an accuracy of ± 1 rpm is obtained.

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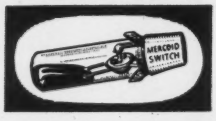

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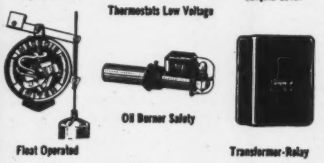

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NEW INSTRUMENTS

High-Q Mica Capacitor

New "Type-22R Silver Mike" high-Q silvered-mica capacitor is 0.5 x 0.31 x 0.18 in. Unit is wax-sealed against humidity. Withstands operating temperature of 100 C. Ratings are: 300 v. d.c. working from 5 mmf. to 510 mmf., and 500 v. d.c. working from 5 mmf. to 420 mmf. Standard capacity tolerance is ± 5 percent. Also available in ± 20, ± 10, ± 13, and ± 2 percent, or ± 1 mmf. (whichever is closer).—*Cornell-Dubilier Electric Corp., South Plainfield, N. J.*

Mention No. 645 when filling out card.

Miniature Capacitor

New "Type 123Z" microminiature tubular capacitor is rated at 85 C. and is capable of operating at 100 C. Measures only .175 in. in diameter by 7/16 in. long.—*Aerovox Corporation, New Bedford, Mass.*

Mention No. 646 when filling out card.

Solenoid

New solenoid is available in 110, 220, and 440 voltage ranges with 0.625-in. maximum stroke, and rated pull or push from 4 to 10 pounds against gravity; is dimensionally interchangeable

with standard solenoids. Features are: simplified construction, fan-proof laminations, "T"-shaped armature, low-temperature operation, shock-proof backstop.—*Dep't C. A, Practical Electric Co., 4505 Oakwood Blvd., Melvindale, Mich.*

Mention No. 647 when filling out card.

Pilot Light

New "Model 1010 Omni-Glow" pilot light has long life, low power-consumption and extreme ruggedness. Uses neon light encased in nylon tube which slips

NEW INSTRUMENTS

through mounting panel. Fresnel lens is available in colors. Operates on 75 to 250 a.c. or d.c. with practically no heat. Withstands vibration, shock, and voltage overloads.—*Industrial Devices Inc., Edgewater, N. J.*

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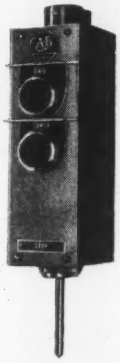
Pendant Control Station

New "Bulletin 800T" pendant push-button station is oiltight. May be obtained in sizes having from three units to 10 units (including stop). Standard

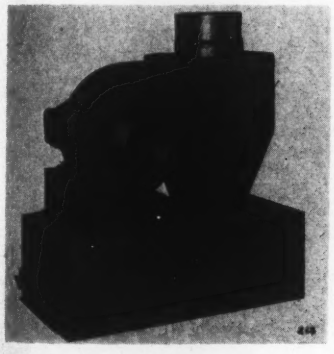


stop unit is a wobble stick in bottom of enclosure; furnished also as mushroom head mounted in bottom or in front of enclosure.—*Allen-Bradley Co., Milwaukee, Wis.*

Mention No. 649 when filling out card.

Filterless Dust Collector

New "Model 4N20 Dustkop" dust collector requires only 12 x 23 in. floor space and develops 437 cfm. and 5000 fpm. velocity at inlet. Motive power is ½-hp. motor driving self-clearing pad-



dle-wheel fan. Dust-laden air carrying shavings, chips, dust, dirt, along with obnoxious odors, toxic fumes, etc. are sent into cyclone separator. Odors, fumes, and dusts are exhausted to out-of-doors through outlet at top of cyclone. Operates on 110-v. single-phase 60-cps. power. May be had for 220- or 440-v. three-phase 60-cps. power.—*Aget-Detroit Co., Ann Arbor, Mich.*

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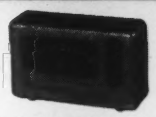

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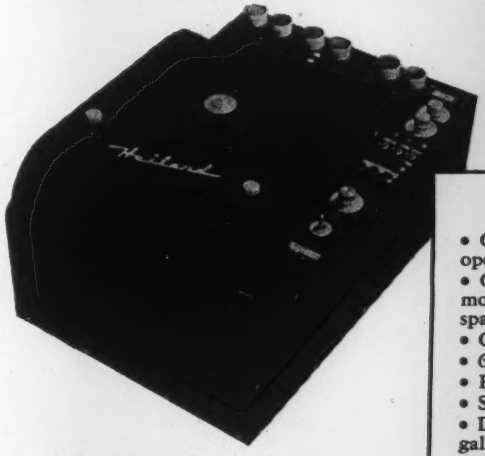

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AUTOMATIC OSCILLOGRAPH RECORDER

Affording complete accessibility from operating surface and requiring only a minimum of space for mounting, the HEILAND A-708 meets the exacting specifications of research and development personnel in aircraft flight testing, laboratory and industrial testing.

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- 6 to 24 channels
- Paper widths 5", 8", 12", 18"
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- Flexibility of operation
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- Adjustable automatic record length

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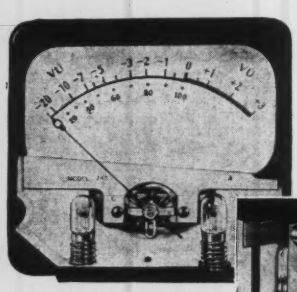

Cutaway views showing positions and connections of lamp assembly.

EXCELLENT LIGHT DISTRIBUTION affords EASE IN READING. GLARE REDUCED to a minimum by retaining COMPACT DESIGN of front case extension.

REFLECTED LIGHT PRINCIPLE permits use of standard METAL DIALS eliminating translucent materials that discolor with age and use.

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Two 3.8 volt STANDARD BULBS are used and connected in series.

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in inch ounces . . . inch pounds . . . foot pounds All Sizes from 0-6000 ft. lbs.

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Series 570-600
Pointer-Type
D-C Galvanometer

Here is a new addition to the line of G-M galvanometers. It is a completely assembled unit featuring an Alnico magnet for greater stability of calibration and is new high in sensitivity. Easily installed and replaced, requires only 2¾" below the mounting surface. Rugged construction throughout. Three models, with sensitivities per mm. division of .06, 0.10 and 0.20 microamps.

Write for specifications and prices on these and other galvanometers

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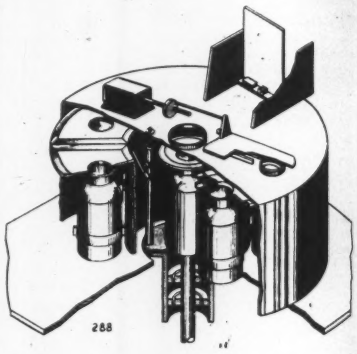
NEW INSTRUMENTS

Directional Dirt-fall Collector

New instrument for analyzing air-pollution problems tells direction from which dirt comes. Amounts of collected materials are correlated with Weather-

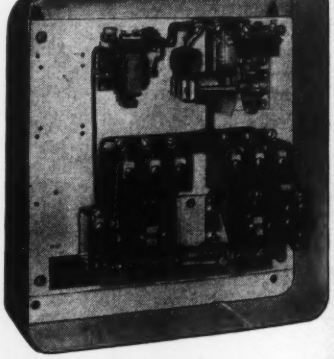


Bureau Wind data. Instrument consists of eight jars in circle with ninth in center. Jars are covered by canopy with one hole at outside edge and another at center. Wind blowing at velocity greater than 3 mph. uncovers outer hole and turns canopy so that dirt is collected in jar corresponding to wind direction.—*Eberbach and Son Co., Ann Arbor, Mich.*

Mention No. 651 when filling out card.

Laundry Washer Control

New "Bulletin 723" laundry washer control panel is for use with squirrel-cage motors driving washing machines. To prevent tangling of clothes, washer



cylinder is operated in one direction for certain time, then reversed and rotated in opposite direction. Dwell period is provided between reversals of machine. Control panels provide four reversals per min. with adjustable dwell period.—*Allen-Bradley Co., Milwaukee 4, Wis.*

Mention No. 652 when filling out card.

NEW INSTRUMENTS

Decade Resistor Box

New "Model-2" decade resistor box uses 10-percent RTMA series. Total of 72 values available from 10 ohms to 8.2 megohms. Values per decade are 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, and 82. Accuracy is ± 2.5 percent. Maximum ratings: 2 watts to 82,000 ohms; 450 v. above 100,000 ohms.—*Rochester Electronics Co., Inc., Box 227, Penfield, N. Y.*

Mention No. 653 when filling out card.

Radioactivity Warning Label

New pressure-sensitive tape has radioactivity symbol and word "RADIOACTIVITY" printed in magenta on yellow background (approved radiation warning colors). Tape is arranged for small pieces to be easily torn off. Each design is 1.5 in. long. Roll is 215 ft. long, one in. wide, and can be used on standard holder.—*Nuclear Instrument and Chemical Corp., 229 West Erie St., Chicago 10, Ill.*

Mention No. 654 when filling out card.

Humidity Indicator

New "Humigraf" humidity indicator consists of a card measuring 6.75 × 2 in. with a vertical column of seven color spots denoting relative humidity from 10 to 70 percent. Changes in humidity cause spots to turn color and reading is made at top blue spot. For small changes in R.H. card responds in 10 min.; response time is 30 min. for a change of 40 percent.—*Andrew Technical Service, 3805 N. Clark St., Chicago 13, Ill.*

Mention No. 655 when filling out card.

BOOKS RECEIVED

INFRARED RADIATION THERAPY SOURCES AND THEIR ANALYSIS WITH SCANNER. By Leopold Rovner. Charles C. Thomas, Springfield, Ill., 1950. Flexible binding, 6½ x 10 inches, 35 pages. Price $1.50. Discusses the scanner survey method of radiation therapy; coverage patterns observed with various type bulbs.

BASIC ELECTRICAL MEASUREMENTS. Edited by Melville B. Stout. Prentice-Hall, Inc., New York, 1950. Cloth, 5¾ x 8⅝ inches, 504 pages. Price $7.75. Intended for use as an undergraduate text and presents the methods that are most important and most frequently used in present-day practice.

ENCYCLOPEDIA ON CATHODE-RAY OSCILLOSCOPES AND THEIR USES. By John F. Rider & Seymour D. Uslan. John F. Rider, Inc., New York, 1950. Cloth, 8½ x 11 inches, 992 pages. Price $9.00. The text describes and discusses completely all types of cathode-ray oscilloscopes and synchroscopes manufactured between 1940 and 1950. Uses as well as theory are examined and discussed.

INTRODUCTORY QUANTITATIVE ANALYSIS. By Ernest H. Swift. Prentice-Hall, Inc., New York, 1950. Cloth, 5⅝ x 8⅝, IX plus 534 pages. Price $5.25. Prepared as a text for a 2 semester course with 6 hour weekly lab to enlarge and coordinate a background of factual inorganic chemistry. Appendix includes questions, problems, demonstration experiments, tables, reagents and equipment.

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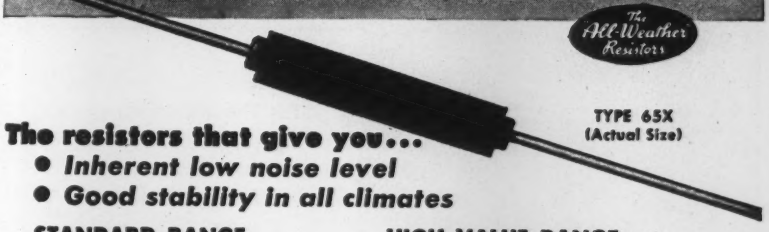

TYPE 65X (Actual Size)

The resistors that give you...

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STANDARD RANGE

1,000 OHMS TO 9 MEGOHMS

These resistors are used extensively in commercial equipment, including radio, telephone, telegraph, sound pictures, television, etc. They are also used in a variety of U. S. Navy equipment.

HIGH VALUE RANGE

10 TO 10,000,000 MEGOHMS

This unusual range of high value resistors has been developed to meet the needs of scientific and industrial control, measuring and laboratory devices — and of high voltage applications.

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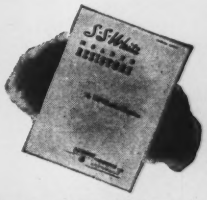
It gives details of Standard and High Value Resistors, including construction, characteristics, dimensions, etc. Also described are S.S. White 80X Resistors, designed for extremely high voltage equipment. Copy with Price List sent on request.



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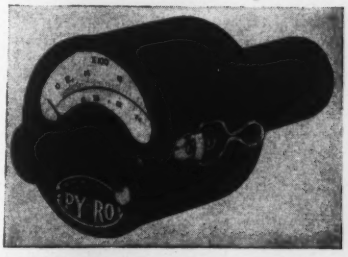

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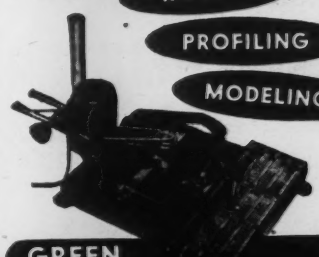

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Model 112

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Also for Alignment and Tracking of UHF Receivers

Specifications:

FREQUENCY RANGE:
300 to 1000 Megacycles.

FREQUENCY CALIBRATION ACCURACY: ±0.5%

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Maximum varies with frequency between 0.3 volt and 2 volts. Adjustable over 40 db range.

OUTPUT IMPEDANCE:
50 ohms.

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12½" x 13½" x 8".
Weight 22 lbs.

This extremely stable oscillator, with individually calibrated, direct-reading frequency dial, was designed for many applications in UHF engineering.

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RADIOGRAPHIC INSPECTION

Continued from page 655

necessary that the work be adjusted to proper position instead of adjusting the machine into position, as with the X-ray machine. It has a smaller focal length. Owing to its low-contrast picture, it does not reveal small flaws which may be unacceptable. Its use should be supplemented by Magnaflux inspection.

The *reflectoscope* transmits short impulses of high-frequency vibration into the steel and observes the magnitude of the reflected impulses. Its use is limited to machined or smooth surfaces. It has come into wide use for examination of highly alloyed steel-sections of modern high-pressure, high-temperature steam-turbines.

Although *Magnaflux* is limited to a penetration of approximately ¼ inch below surface, it is used extensively by Ordnance as a supplement to visual and radiographic inspection.

Contract, Drawings, and Specifications

In production of an item such as steel casting, definite and specific guides must be established. These guides are the contract, drawings, and specifications. In procuring Ordnance material, the drawings and specifications are the controlling influences. It is essential to read and study the drawings and specifications. When this procedure is not followed, the result is production delay and monetary loss.

The contract, drawings, and basic specifications are named in the order of precedence. The contract describes the item with the applicable drawings and specifications. The drawing contains notes that receive consideration over any conflicting detail in the basic specifications. These notes state the special tests and detailed requirements of the specification. They indicate the radiography required and the drawing number of the position chart applicable to the particular casting.

Where there are sections of varying thickness or intricate design, it is generally accepted that the casting will contain some shrinkage. The process of solidification of the metal eliminates the possibility of obtaining a perfectly sound section through the casting at all times. Therefore, Ordnance has provided the *position chart* or drawing to cover those critical areas and to specify the governing standards for acceptability.

The steel-casting *specification* includes detailed specifications covering radiography of weldments, radiography of steel casting, and applicable standards for the acceptance of films. The routine procedure for radiography inspection is given in the basic specifications.

The radiography specifies that all machines under 1,000,000 volts must be qualified. Detailed instructions with test plates are supplied by the Watertown

Arsenal. This qualification establishes a d/t ratio (a characteristic of the particular tube) to be used in the machine, where d is the distance from the tube to the top surface of the section to be radiographed and t is the distance from the film to the top surface. The operator performing this work is required to be qualified by submitting films taken under a similar procedure used in qualifying the machine. The films are developed, and records are made of film used, development temperature, development time, fixing time, and washing time. This report is forwarded with the films to Watertown Arsenal to be compared and evaluated with the standards for the specific test block used in making the qualification test.

In radiographing production casting at specified intervals, let us say every thirtieth casting, one does not assume that all intervening castings radiographed are good. As stated in the basic specification for steel castings, radiographic inspection is to be used more as a guide to improve and control quality.

HYDRAULIC SERVOCONTROLS

Continued from page 651

The addition of the bypassed piston makes resetting of the control point, or reset, possible. A displacement of the controlling piston is paralleled by the "proportional" motion of the feedback piston. The bypass around the spring-biased feedback piston provides reset action at a rate adjustable by means of the bypass valve.

Rate.—Rate signals can be used to make the position of the piston proportional to the *rate* of changes in error signals. Rate signals can be obtained by the same methods used in pneumatic and electric circuits. Gyro signals are often used in applications such as automatic steering devices and automatic pilots.

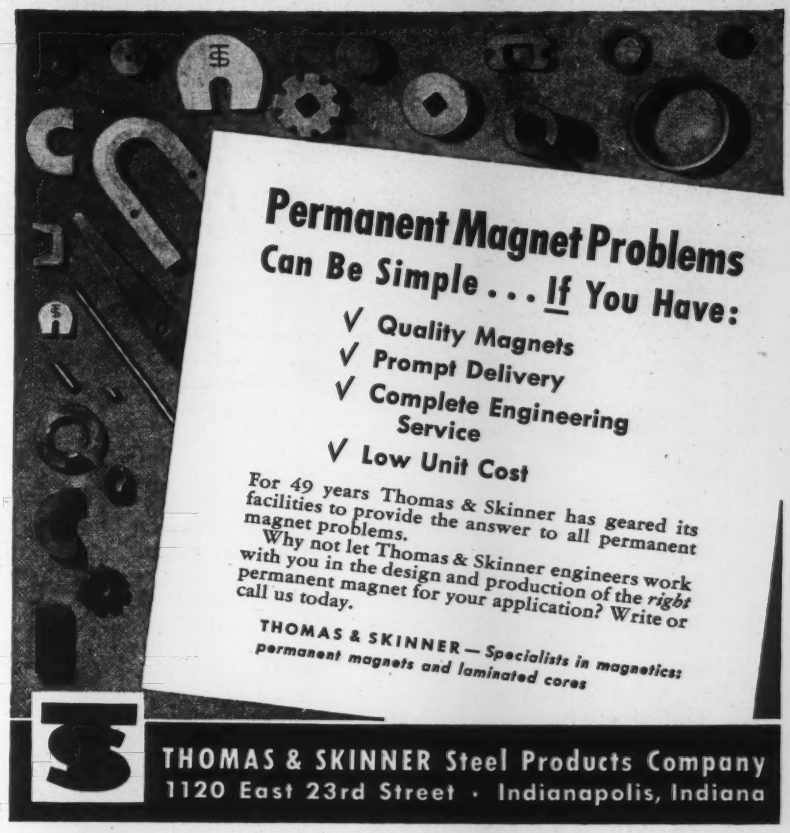
APPLICATIONS

Servocontrols in the steel industry are applied to various processes and to various kinds of equipment.

Typical examples are:

1. Furnace controls for combustion of single or multiple fuels, draft controls, and reversing controls.
2. Blow and exhauster controls and related turbine and other prime-mover controls.
3. Coke-oven, blast-furnace, and stove controls.
4. Power servos which position valves or dampers in response to the output of air-operated controllers.
5. Remote electrohydraulic positioning-devices as used in charging equipment and reversing mechanisms.
6. Boiler controls, including reducing valves, feedwater level, desuperheater, and other associated devices.

In conclusion, hydraulic controls are particularly well suited for certain fields of operation. However, the choice of any one system or circuit should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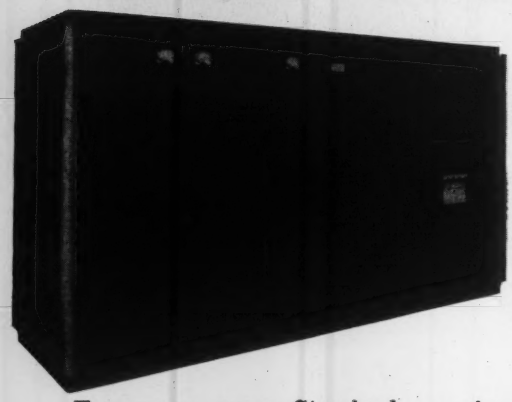

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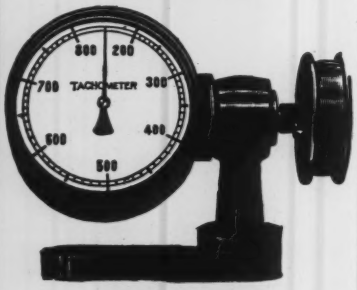

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PNEUMATIC SERVOMECHANISMS

Continued from page 649

power output is shown also in Fig. 9. As thrust increases, speed decreases.

A load with sufficiently high inertia can cause instability of any type of positioning servo—pneumatic, hydraulic, or electric. The attachment of a proper oil-dashpot (viscous damper) to the output shaft restores stability.

Damping.—The effect of the output damping of the dashpot is analyzed easily. The resistance of the dashpot increases directly with the piston speed. Thus the thrust applied to the inertial load is less at a given cylinder speed by the amount absorbed by the dashpot. In other words, the automatic decrease of thrust applied to the inertial load as piston speed increases accounts for the stabilizing factor.

The damping is controlled by the dashpot force-speed constant. This constant is adjustable by a needle valve in the dashpot. In practice, no dashpot is necessary because the same effect is obtained by cylinder design.

As shown in Fig. 9, the speed-thrust characteristic of the cylinder displays the general damping characteristic of a constant-thrust device with a dashpot. However, as the slope is a built-in characteristic of a particular cylinder design, it is not adjustable.

Assuming that the present upper limit of the air supply is 100 psi., the damping curve can be made more steep and the peak thrust can be increased by increasing the cylinder size, as shown in Fig. 10. Air cylinders in general have somewhat larger bores than oil cylinders. Nevertheless, the practical operating speeds are higher than for oil cylinders.

The ratio (N) of the damping actually present to that required for critical damping is a function of the dimensionless parameter $F/S \times T/M$, where

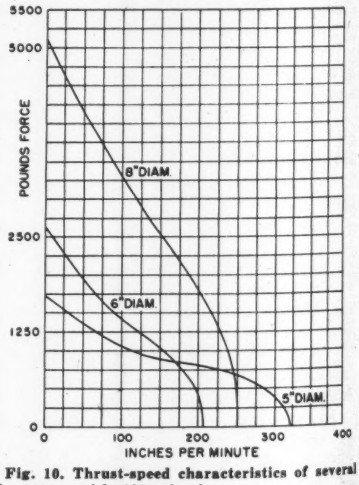

Fig. 10. Thrust-speed characteristics of several air servos with 100-psi. air.

F/S is the actual thrust-speed characteristic slope, T is the no-load cylinder traversing time, and M is the inertial mass.

Air cylinders can be designed to have high speed, inertial-load stability, and good characteristics with "sticky" loads.

Conclusion

Steel-mill engineers are now using pneumatic control apparatus where it meets the requirements of their particular industry. Study of the principal limitations of air as the control fluid gives background to the extensive use of high-performance air-operated systems. Without doubt, the continuing technical advance in this control field will be paralleled by advances in competitive systems. It is by this endless competitive process that free industry assures itself of the leadership accruing to the wisdom of the open mind.

NON-CONTACT GAGING

Continued from page 654

The spindle illustrated is used for checking ½ of a V-8 engine. A four-column unit is used for each bore in order to check the cylinder diameter at four different places.

Fig. 11. Instrument for gaging, classifying, and sorting piston pins.

An instrument with an air gage and an electronic circuit for classifying and sorting is illustrated in Fig. 11. Piston pins are fed automatically into the machine. In one inspection, the pins are checked for taper and diameter, and are classified in 0.0001-inch steps. Those above or below tolerance range are sorted into one group; tapered pins are sorted into another group; pins within the 0.0005-inch tolerance are classified in 0.0001-inch groups and shuttled to the proper chute.

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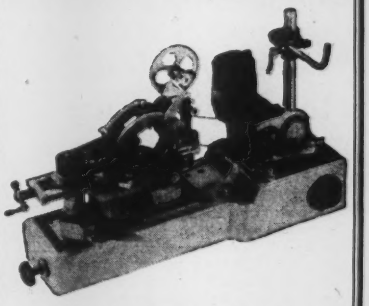

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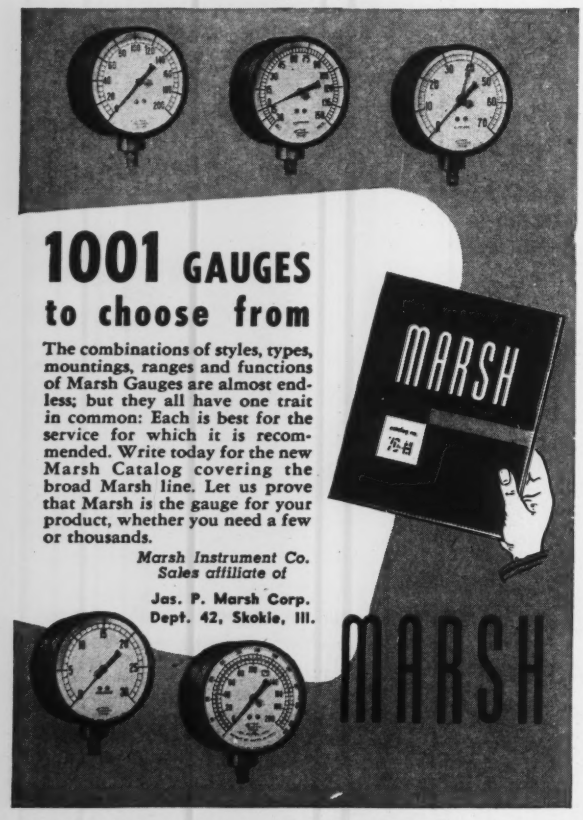
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INSTRUMENTS ON THE MARCH

Ceramic Thickness Gage

WASHINGTON, D. C.—An electronic thickness gage for measuring the thickness of nonconducting coatings on nonmagnetic metals has been developed at the National Bureau of Standards, according to Technical Report 1442. The new instrument provides a non-destructive measurement. These measurements have become important with the increasing use of ceramic materials as protective coatings for metals and alloys in high-temperature service, on which magnetic thickness gages cannot be used.

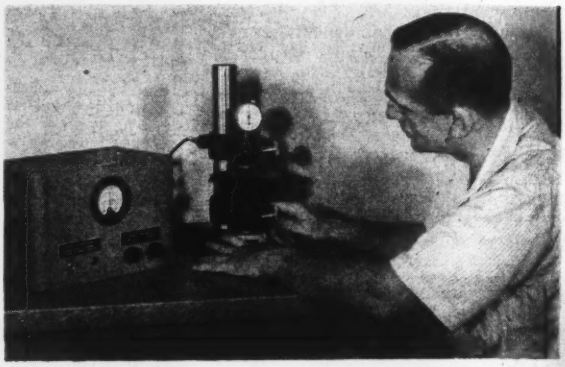

Fig. 1. Ceramic thickness Gage.

The instrument (Fig. 1) consists essentially of a small coil, an inductance indicating system, and a device for positioning the coil and measuring its distance from the test surface. The probe coil (Fig. 2) is housed in a cylindrical plastic test head. A small plastic rod attached to a dial indicator extends axially through the coil to serve a feeler element. The test head is mounted in a heavy gage stand which provides for controlled movement of the test specimen with respect to the probe coil.

The electronic components of the 500-kc. oscillator and the bridge-type inductance indicating system are housed in a small cabinet and connected to the test head by a removable shielded cable. Bridge balance is indicated by a sensitive galvanometer. The measurement is based upon the change in inductance of the probe coil with change in proximity of the coated-metal surface. This change may be

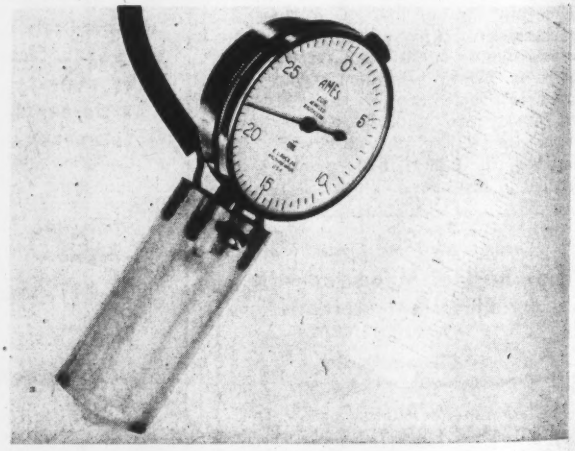

Fig. 2. Probe coil.

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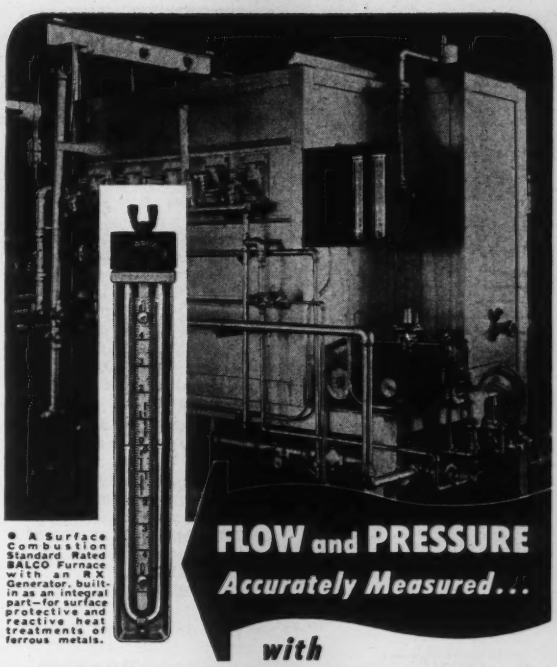

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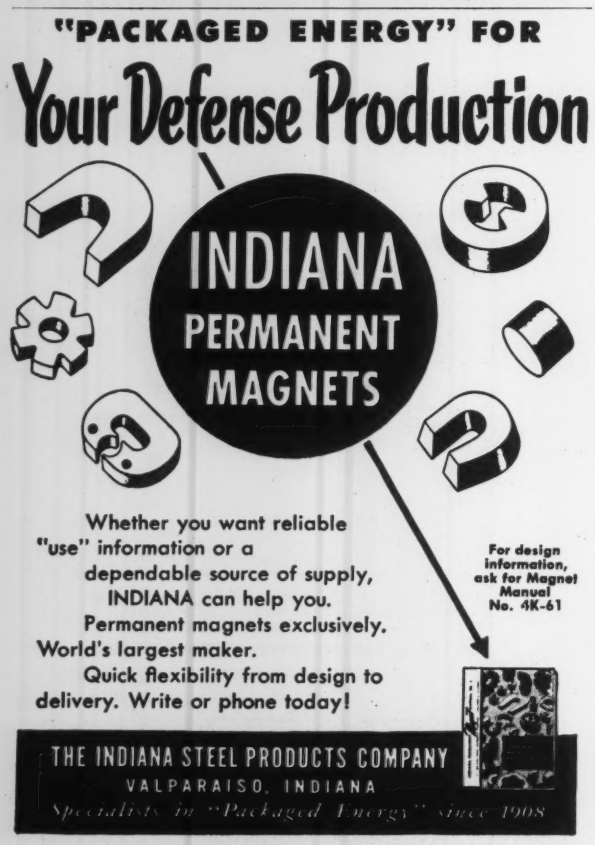
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visualized by considering the combination as a transformer, with the probe coil acting as a primary which is coupled to the metal surface, which acts as a short-circuited secondary. The inductance of the primary varies with this coupling, and hence with the proximity of the metal surface.

Before a thickness measurement is made the instrument is calibrated on an uncoated specimen identical in size, shape, and composition with the coated specimen to be tested. The reference specimen is placed on the table of the gage stand and the table is raised until the feeler of

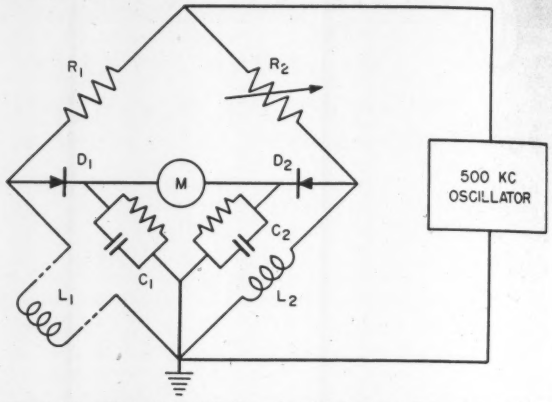

Fig. 3. Simplified schematic diagram of inductance balance indicator.

the dial gage is in positive contact with the surface. The dial gage is then set at zero and the bridge rheostats (Fig. 3) are adjusted so that the galvanometer is zeroed. The inductance of the probe coil in the presence of the uncoated metal specimen is thus established as a reference value. The table is lowered and the uncoated metal specimen replaced by a coated specimen. The table is again raised until the galvanometer reads zero. The thickness of the coating is then given directly by the dial-gage reading. The coating material has a negligible effect on the electric field at the frequency used.

The bridge circuit is energized by a 500-kc. oscillator employing a dual triode in push-pull. A peak-reading rectifier circuit, consisting of a crystal diode in series with a capacitor and resistor in parallel, is connected across the probe coil (L_1). In order to obtain a comparison voltage with the same sources of extraneous variation as the probe voltage, a reference coil (L_2) is arranged in a similar circuit and fed from the same oscillator through a variable resistance, which can be adjusted to equalize the a-c. voltage drops for both coils. The sensitive galvanometer, protected against overload by two crystal diodes in shunt opposition across the meter, indicates any unbalance between the two branches of the bridge.

Although this instrument was developed primarily for the measurement of the thickness of ceramic coatings on turbine blades and other high-temperature parts of aircraft power plants, it should be useful for thickness determinations of paint, plastic, and other nonconducting films on aluminum, brass, copper, stainless steel, and other slightly magnetic or nonmagnetic metals.

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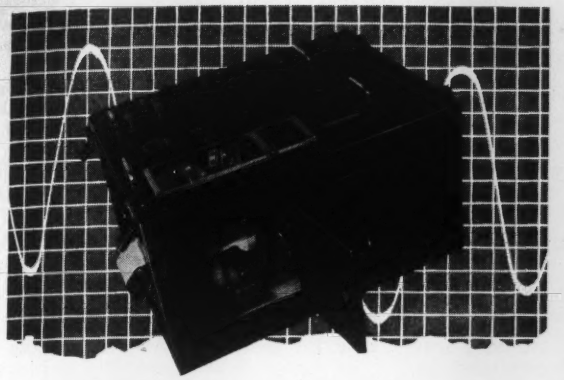

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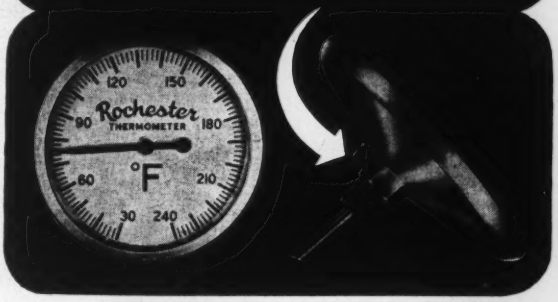

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stained largely with a blue dye, with a tinge of red. Under polarized light, the silica particles appear either predominantly blue or predominantly red. As the particles are easily identified by their color in either case, they can be readily measured as to size and quantity.

Although this microscopy technique was designed for observing silica particles, it is applicable for determining the presence of other toxic dusts such as chrysotile, and causative agent of another lung disease called asbestosis.

Magnetic Permeameter

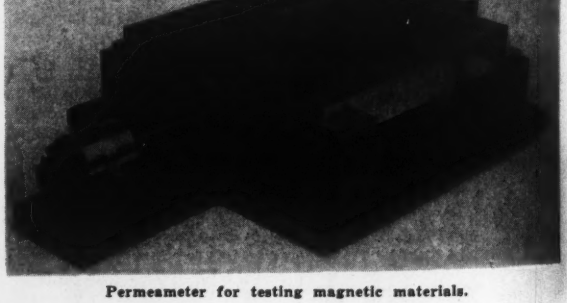
WASHINGTON, D. C.—An improved magnetic permeameter for the precise testing of magnetic materials at magnetizing forces up to 300 oersteds has been developed at the National Bureau of Standards, according to Technical Report 1457. The new instrument, known as the MH (medium magnetizing force) Permeameter, is absolute in principle—that is, its constants are derived from its own dimensions so that calibration by reference to any other permeameter is not required. It is as simple and convenient to operate as any of the commercial permeameters now in general use in industrial laboratories.

Of basic importance in the production and utilization of magnetic materials is the accurate determination of their magnetic properties. Normal induction and hysteresis data are commonly obtained in industrial laboratories by use of several types of commercial permeameters. To secure uniformity in this work, specially prepared test specimens of magnetic materials, which are used by the various laboratories as reference standards in calibrating their permeameters, are periodically submitted to the Bureau's magnetic measurements laboratory for test.

For many years the testing of magnetic reference standards has been carried out with the Burrows Compensated Double-Yoke Permeameter, an instrument developed at the Bureau in 1909. Although this permeameter gives highly accurate results when properly used, it is not nearly as convenient as the commercial permeameters now available.

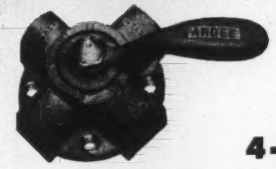
The permeameter designed at the Bureau consists essentially of a main magnetizing coil, which surrounds the specimen, and two symmetrical U-shaped core pieces, or yokes, which complete the magnetic circuit and thus promote a uniform cross-sectional distribution of magnetic flux in the specimen. The yokes are arranged to form a square bisected by the specimen—a bar of rectangular cross section—and are supported by two end pieces, which are rectangular bars of magnetic material at either end of the magnetizing coil. The end pieces, which rest on four bakelite blocks, also support the specimen and provide for good magnetic contact between the yokes and the specimen. Auxiliary magnetizing coils, which encircle the ends of the yokes and the supporting end pieces, promote a uniform longitudinal distribution of flux in the specimen by overcoming the contact reluctance between the specimen and the yoke. The flux distribution in the region about the center section of the specimen is thus improved, and the accuracy of measurements of magnetizing force is correspondingly increased.

Values of flux density, B, are obtained by measuring the electrical impulse in a test coil surrounding the bar at the



Permeameter for testing magnetic materials.

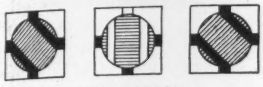
VACUUM CONTROL



WITH

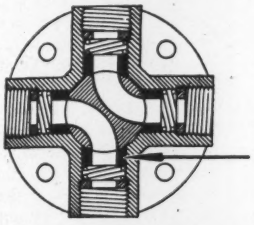
ARDEE

4-WAY VALVES



FLOW DIAGRAM

The positive, tight shut-off characteristic of Ardee 4-way valves has won them approval in extreme vacuum service—at instrumentation limits.



Valves are available in pipe sizes ¼, ⅜, ½, and ¾ N.P.T. Bodies are either brass or aluminum, with brass rotor, and molded tubular seals of resilient materials suitable for the specific service requirements.

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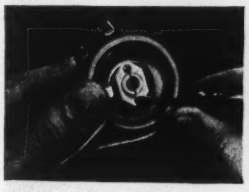

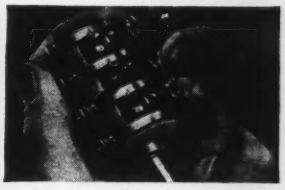

Among the biggest features of Fairchild's new Type 746 precision potentiometers are their simpler, more accurate phasing adjustments. At the factory, a specially designed adjustment permits accurate wiper-arm phasing so that terminal strips are perfectly aligned. For the ultimate in phasing accuracy, or for last-minute field modifications, final adjustment is made by loosening connecting-band screws between cups and rotating the housings.

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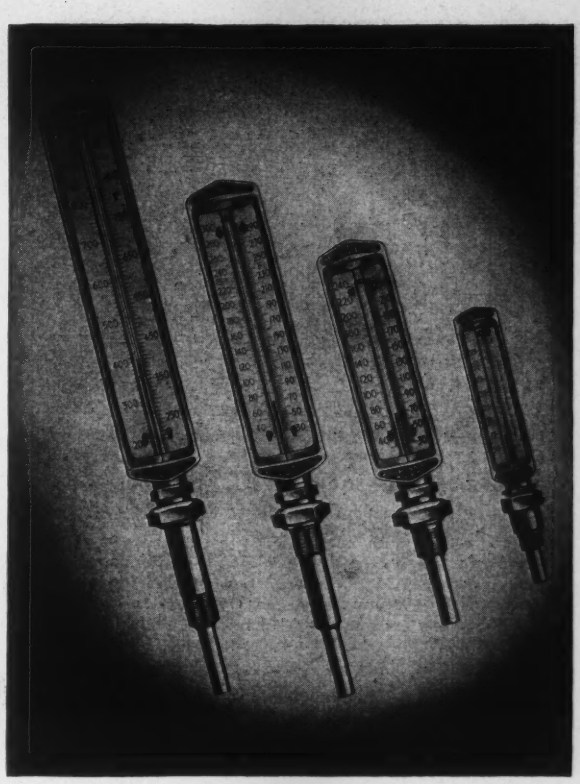

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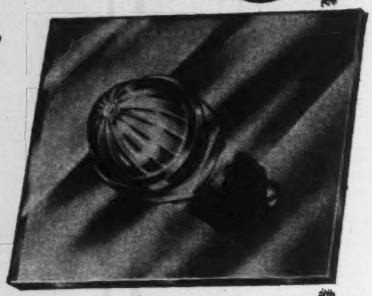

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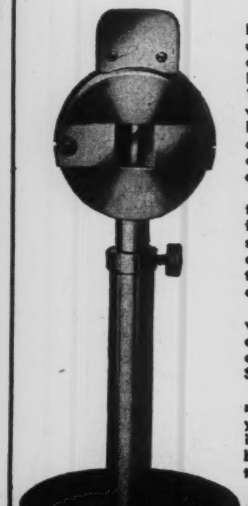

For many years the thermopile has been the accepted instrument for measuring Radiant Heat from Radiant Heaters at the American Gas Association Testing Laboratory in Cleveland, Ohio. Since 1930, when Vandaveer first described his work in this field,* an Eppley thermopile has been used for this purpose in hundreds of tests and the results have been consistent and accurate to within 1 per cent.

This is but one of many applications in the field of radiant energy measurements for which Eppley Thermopiles are ideally suited. They may be obtained with windows of different materials, and various types of black are available for receiver coatings.

All Eppley Thermopiles are supplied with a certificate of calibration, this calibration being made against a Standard Lamp from the National Bureau of Standards.

If you have a problem involving the measurement of radiant energy we invite you to write us, describing your problem in as much detail as possible. We will be glad to make recommendations and there will be no obligation.

*Vandaveer, *Industrial & Engineering Chemistry*, Vol. 22, page 596, June 1930.

THE EPPLEY LABORATORY, INC.

SCIENTIFIC INSTRUMENTS

NEWPORT, RHODE ISLAND, U. S. A.

middle. An auxiliary test coil whose area-turn value is adjusted to be equal to that of the B-coil is located adjacent to the B-coil, but not surrounding the specimen. As the auxiliary coil is connected in series with the B-coil in such a way that the two currents are in opposition, the galvanometer deflections observed are a measure of the intrinsic flux density rather than the total flux density. This eliminates the necessity of calculating the air-flux correction for bars of different cross-sectional area.

Values of magnetizing force, H, are obtained by means of two H-coils so mounted that they can be made to rotate through 180° in the region adjacent to the center section of the specimen. The H-coils are set one above the other on a rotating brass table and adjusted to equal area-turn values. When these coils are connected in series, with their currents opposing and their axes parallel to the specimen, and are rotated through 180 degrees, the galvanometer deflection observed is proportional to the radial gradient of the field measured outward from the surface of the specimen. The value of H as determined by the deflection when only the upper coil is connected to the galvanometer is then extrapolated to the surface of the specimen by use of the observed value of the radial gradient.

It is estimated that the MH permeameter can be used to obtain values of induction accurate to within about 0.5 percent and values of magnetizing force accurate to within 0.5 percent or 0.05 oersted, whichever is larger. For routine tests, values of either quantity accurate to within 1 percent should easily be possible. As good contact between the yokes and specimen is obtained without the necessity of clamping, uncertainty in results due to the effect of mechanical strain on the specimen is avoided. This is a definite advantage in the testing of high-permeability alloy sheet, which is likely to to be extremely sensitive to strain.

Multiple Strain-gage Tests

PHILADELPHIA, Penna.—An extensive electronic stress-measurement was successfully concluded recently by Boeing Airplane Company in elaborate structural tests of the B-47 Stratojet bomber at Wichita, Kan. Thirty-two tension load cells incorporating special Baldwin SR-4 bonded resistance-wire strain-gages were used. All cells were wired to two self-balancing indicators. The indicator was calibrated in percent load rather than pounds. All cells were matched and calibrated to rated capacity at 100 percent on

Electrical indicators for indicating loads applied through strain-gage load cells.

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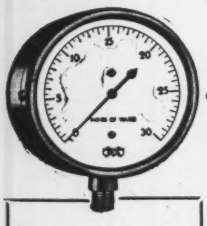

Marshalltown Figure 83 is an extremely sensitive gauge that uses a carefully seasoned bronze diaphragm to accurately measure very low pressures. It is used extensively on many types of natural gas installations for checking the low pressures.

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the indicator. Each reading of each cell required about 10 seconds.

Most of the 32 cells were installed in the loading system in series with hydraulic rams, which were pressured by a battery of manually operated jacks. Hydraulic pressure gages were read for approximate adjustments, but final adjustment or corrections were made from the Baldwin SR-4 load cells. These cells, which have capacities of 20,000 lb. and 100,000 lb., were checked periodically.

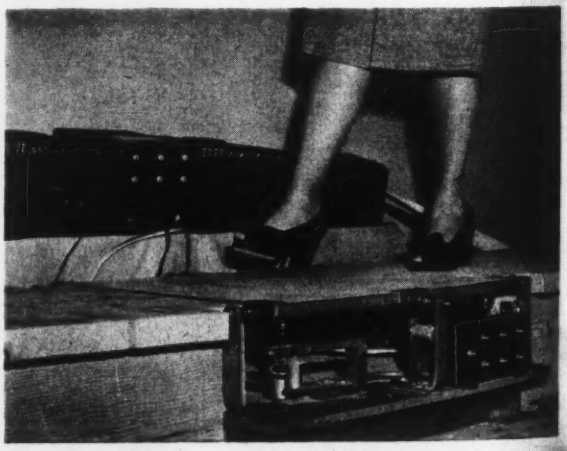
The load cell is basically a bar of steel on which special 250-ohm strain gages are bonded. They have threads on both ends for loading fixtures of any desired type. The bar is protected by a steel case in which it is sealed by means of "O" rings. The largest cell is only 15 inches long and 3 inches in diameter at the threaded ends. The arrow in the illustration points to a load cell. Leeds & Northrup Type-G Speedomax indicators were used for measurements.

Electronic Stepmeter Reveals Mechanics *of* Walking

WASHINGTON, D. C.—The elimination of the hazards imposed by slippery walkway surfaces—responsible each year for a large number of injuries and deaths—is the principal objective of a research project at the National Bureau of Standards, according to Technical Report 1526. To obtain basic quantitative data on some of the factors involved in the slipperiness of walkways, the Bureau has devised an electronic stepmeter which measures the three components of force produced between the foot and the floor in normal walking.

Human locomotion is accomplished by the force exerted by the leg on a walkway surface. Gravity and the friction between the two contact surfaces are important factors.

The electronic stepmeter consists primarily of a 2-foot square platform mounted on ball bearings, which are attached to four J-shaped springs. The four sides of the platform bear against ball bearings attached to L-shaped springs, which are kept under slight tension so that all springs follow the horizontal motion of the platform. Electromechanical pickups, an adaptation of the mutual-inductance electronic micrometer previously developed at the National Bureau of Standards, are mounted adjacent to the appropriate springs. Deflections of the springs due to forces exerted produce output voltages in the pickups proportional to the forces in each of three directions—vertical, longitudinal, and transverse. The output voltages are amplified and recorded on a time scale by an oscillograph.



Electronic stepmeter measures components of forces exerted on walkway

Other "On the March" items on page 656

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This newly-developed FYRITE Test Set comprises two separate indicators—one for direct CO_2 analysis, the other for direct Oxygen analysis. Both instruments employ the fundamental principle of chemical absorption. The absorbing fluid used in each instrument is selective in its affinity for CO_2 or Oxygen, respectively, and is not affected by the presence of other gases. The instruments are portable; require no setting-up, have no valves or leveling bottle to manipulate. They are packed in a compact carrying case together with a complete rubber aspirating assembly for connecting either instrument to the desired sampling point.

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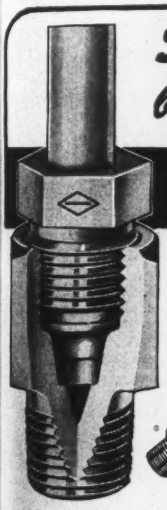

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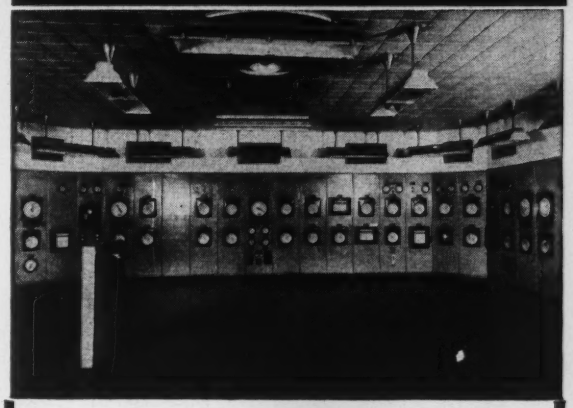

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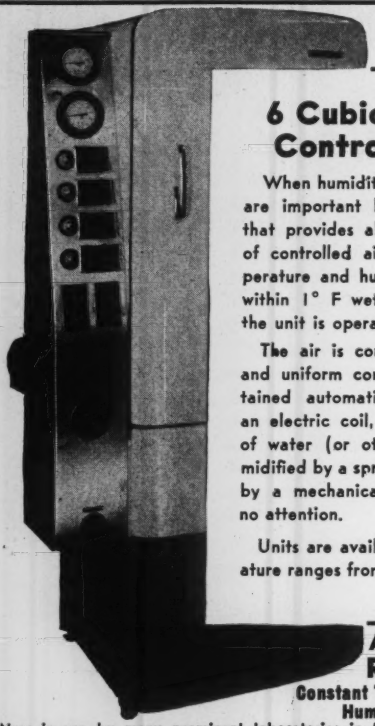

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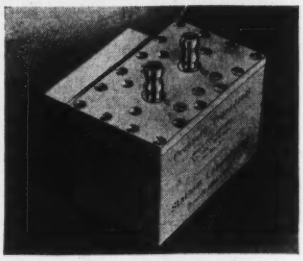

The Model P69 pressure transducer is designed for long life and excellent performance under conditions of vibration and acceleration such as are encountered in flight test and guided missile applications. This dynamically balanced, temperature compensated transducer is offered for the measurement of gage, differential, or absolute pressure. The full bridge of the transducer will operate successfully with a wide variety of controlling, indicating, recording, and telemetering circuits.

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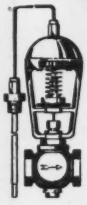

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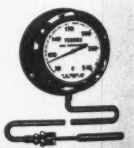

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THE SECRETARY'S PAGE

Sixth National Instrument Exhibit

A YEAR ago there existed considerable skepticism concerning the selection of the City of Houston, Texas, for the location of the Sixth National Instrument Exhibit. It was thought by some that this location was too far removed from the large industrial centers: that there was insufficient industry in Houston area to justify exhibiting by the instrument manufacturers; that the expense involved would keep many away; etc. etc. This skepticism rapidly disappeared shortly after the sale of booths in the Exhibit was opened and when it was announced that reservations for space were pouring in at a rate unprecedented in the entire history of the Instrument Exhibit.

Today there is nothing but enthusiasm for attending what will be the largest instrument Exhibit ever held in America. Of the 215 booths laid out for sale, 213 have been reserved as of May 25, 1951. There is no question but that the remaining two booths will be sold before the opening of the Exhibit. In addition we have not as yet received final word from the Armed Services. Should they decide to exhibit, at least ten booths will be required for their displays. The space for these additional booths is available and we also might be able to furnish space for other manufacturing exhibitors who decide to come in during the three months remaining before the opening date of the Exhibit.

A few interesting facts on the exhibit are as follows: 215 booths, 133 manufacturers, 8 manufacturer's representative companies, 1 trade association, 4 cooperating societies, 2 educational institutions.

These exhibitors are making every effort to insure that the Exhibit will be as complete as possible. There will be few, if any, instruments manufactured in this country, both new and old alike, which will *not* be on display. Our questionnaires sent to each exhibitor inquiring about the products to be exhibited have already been returned with few exceptions; and the products to be shown read like a directory of the products of the instrument industry.

During times of war and threats of more war, the new developments of science and industry are expected to increase rapidly; but we had not anticipated the veritable PARADE of new products that have been reported by the instrument manufacturers as being ready for display at Houston.

The Sixth National Instrument Exhibit will be a Great Show. Plan to be there. It will prove more than worth your time and expense.

Section Secretaries, Meeting Data and Programs

AKRON
Fred Appel, 932 Columbia Ct., Barberton, Ohio. Tel: SH 3440
Fourth Tuesday, 7:30 P. M., Akron Y.W.C.A.

ALBUQUERQUE
E. J. Burda, Sandia Corp., P. O. Box 5800, Albuquerque, N. Mex. Tel: 5-5511
First Monday, Meeting at 8:00 P.M., Science Lecture Hall, Univ. of N. M.

ARUBA
E. H. Pfeffer, P.O. Box 291, c/o Lago Oil & Transport Co., Ltd., Aruba, N.W.I.
First Tuesday, 7:15 P. M., Engr's Club.

ATLANTA
D. M. McRae, 150 Nassau St., Atlanta, Ga.
Fourth Monday, Meeting at 7:45 P.M., Ga. Institute of Technology.

BALTIMORE
W. A. Dickinson, 2716 Dunbrook Ct., Baltimore 22, Md. Tel. Dundalk 2272J
Second Friday, Meeting at 8:00 P.M., Engr's. Club of Baltimore.

BATON ROUGE
John Q. Bass, 1517 Longwood Dr., Baton Rouge, La. Tel: 3-0283
Meeting monthly, L.S.U. Physics Bldg.

BOSTON
Stephen E. Lord, 60 Braintree Ave., Quincy 69, Mass. Tel: MA 9-1066
Last Wednesday, Dinner at 6:30 P. M., Meeting at 7:00 P.M., 99 Club, 99 State St.

CALIFORNIA
D. C. Duncan, Helipot Corp., 916 Meridian Ave., S. Pasadena, Calif. Tel: SY 4-8439
Second Wednesday, Dinner at 6:30 P. M. Meeting at 8:00 P.M., Carolina Dines.

CENTRAL ILLINOIS
Thomas A. Carroll, 721 Hurlburt St., Peoria 6, Ill. Tel.: Peoria 4-8909
First Wednesday, Dinner at 6:30 P.M., Meeting at 7:30 P.M.

CENTRAL INDIANA
Richard F. Rieman, 3550 Euclid St., Indianapolis, Ind. Tel. CH 7462
First Tuesday, Meeting at 7:30 P. M.

CENTRAL NEW YORK
Karl W. Robertson, Minneapolis-Honeywell Reg. Co., 121 Onondaga St., Syracuse.

CHARLESTON
Fred Gilmer, 418 Beech Ave., Charleston, W. Va.
First Monday, Dinner at 6:15 P.M., Meeting at 8:00 P.M., Kanawha Hotel.

CHICAGO
Floyd E. Ertsman, Rm. 1420 Fisher Bldg., 343 S. Dearborn St., Chicago 4, Ill. Tel: WE 9-0686
First Monday, Dinner at 6:30 P. M., Meeting at 8:00 P. M., Shoreland Hotel.

CHINA LAKE
A. H. Staud, 1004 Michelson Lab., USNOTS, China Lake, Calif. Tel: 77882
Fourth Thursday, Meeting at 8:00 P.M., Michelson Lab, USNOTS.

CINCINNATI
L. W. Greene, 181 Market St., Aurora, Ind.
Second Monday, 8:00 P. M., Eng'r. Society Hqs.

CLEVELAND
A. E. Ehrke, 5805 Euclid Ave., Cleveland, Ohio. Tel: Ex 1-5454
Fourth Wednesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Cleveland Eng'r. Society, E. 19th St.

COLUMBUS
W. C. Myers, c/o Battelle Memorial Institute, 505 King Ave., Columbus, Ohio. Tel: UN 3191, Ex. 248
Third Thursday, Meeting at 8:00 P.M., Battelle Auditorium

CUMBERLAND
Clyde Babst, 225 Cecilia St., Cumberland, Md. Tel: 588-W
Tuesday after Fourth Monday, 8:00 P. M., Dinner at 6:30 P. M., Algonquin Hotel.

DETROIT
A. W. Brueckner, 5556 S. Clarendon Ave., Detroit 4, Mich. Tel: TYler 6-9511.
Third Tuesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Rackham Bldg.

EASTERN NEW YORK
W. R. McKegg, c/o Gen. Engrg. & Consulting Lab., G. E. Co., Schenectady, N. Y.
First Tuesday, 8:00 P.M., Dinner at 6:30 P.M.

GULF COAST
W. N. Sloan, E. I. Du Pont de Nemours & Co., Orange, Texas. Tel: 8411 Ext. 444
Third Tuesday, Meeting at 7:30 P.M., Lamar College, Beaumont, Texas.

HOUSTON
I. K. Farley, 2123 Travis St., Houston, Texas, Tel: Charter 2511.
Last Monday, 8:00 P. M., Engineers Club.

KANSAS CITY
H. H. Schmall, 3706 Benton Blvd., Kansas City 3, Mo. Tel: AR 4808
First Tuesday, 7:30 P.M., U. of Kansas City.

LOUISVILLE
C. M. Bosworth, 203 Arbor Park, N., Lo., Ky.
Fourth Tuesday, Meeting at 8:00 P.M., Seagram Auditorium.

MONTREAL
S. J. Mizuhara, 1075 Allard, Verdun, Quebec, Canada. Tel: TR 3252
Last Monday, 8:00 P. M., Mechanics' Institute.

NEW JERSEY
Fred L. Crabbe, Malcolm W. Black & Co., Inc., 41 East 42nd St., New York 17, N. Y. Tel: Vanderbilt 6-2960.
First Tuesday, Dinner at 6:00 P. M. Meeting at 8:00 P.M., Essex House, Newark.

NEW ORLEANS
W. H. Haney, 2927 Music St., N. O. 22, La.
No Regular Date, Meeting at 8:00 P.M.

NEW YORK
F. B. Leslie, 8856 Commonwealth Blvd., Bellerose 6, N. Y. Tel: FI 7-0645
Last Monday, Dinner at 6:00 P.M., Meeting at 7:45 P. M., Hob Nob Club, 108 E. 41st St.

NIAGARA FRONTIER
Mrs. James L. Martin, 697 Potomac Ave., Buffalo 22, N. Y. Tel: GR 1450
Fourth Monday, Dinner at 6:00 P.M., Meeting at 8:00 P.M., N. Y. State Inst. of Arts and Sciences, Buffalo.

NORTH TEXAS
R. E. Byers, 6000 Lemmon Ave., Dallas 9.

NORTHERN CALIFORNIA
S. D. Stillson, 1324 Everett St., El Cerrito, Calif. Tel. Becon 2-7139
Third Monday, 8:00 P. M., E. Bay Area.

NORTHERN INDIANA
J. Baum Beckman, 547 N. Waller Ave., Chicago 44, Ill. Tel: ES 8-7776
First Wednesday, Meeting at 7:30 P.M., Whiting Community Center, Whiting, Ind.

OAK RIDGE
J. Lundholm, Jr., Eff. A-13, Apt. 241, Oak Ridge, Tenn. Tel: 5-6539
First Wednesday, Meeting at 7:30 P.M., Knight's of Columbus Hall.

ONTARIO
John W. Huether, 311 Southerland Dr., Leaside, Ontario, Canada. Tel: HU-7114
Third Thursday, Meeting at 8:00 P.M. Friendship Hall, College St. United Church, Toronto

PANHANDLE
R. E. Harris, 228 Mays Bldg., Amarillo, Texas. Tel.: 31434.
Third Tuesday, Meeting at 8:00 P.M.

PHILADELPHIA
R. A. Trenner, Rm. 306, 3147 Broad St., Philadelphia 32, Pa. Tel: SA 2-7900
Third Wednesday, Meeting at 8:00 P.M., Bellvue Stratford Hotel.

PITTSBURGH
Miss Louise Suckfield, P.O. Box 2038, Pittsburgh 30, Pa. Tel: HI 1-1800
Fourth Monday, meeting jointly with the Technical Committee on Inspection and Gaging. Dinner at 6:30 P.M., Meetings at 8:00 P.M., Roosevelt Hotel.

PRESQUE ISLE
Edwin P. Schuwerk, 445½ Halley St., L. P., Erie, Pa. Tel: 2-3349
Fourth Tuesday, Meeting at 8:00 P.M., G. E. Community Center, East Lake Rd., Erie, Pa.

RICHLAND
R. A. Nederhood, 2003 Trippe St., Richland, Washington. Tel. 5-4442
Second Wednesday, Meeting at 7:30 P.M., American Legion Hall.

ROCHESTER
R. C. Schwarz, Jr., 1201 Granite Bldg., Rochester 4, N. Y. Tel: Monroe 4610R
Fourth Tuesday, Meeting at 8:00 P.M., Univ. of Rochester, Physics Lecture Hall.

SARNIA
J. J. Connors, 272 Elgin St., Sarnia, Ontario, Canada. Tel: 1970 W
Second Friday, 8:00 P. M., Moose Hall.

SOUTH MICHIGAN
W. J. Sprau, 2509 S. Rose St., Kalamazoo, Mich. Tel: 4-7012.
Fourth Wednesday, 8:00 P. M., Dinner at 6:30 P. M., Chicken Charlie's, Kalamazoo.

SOUTH TEXAS
H. C. Givens, La Gloria Corp., P.O. 637, Falfurrias, Texas. Tel: 122-W
First Wednesday. Meeting at 7:30 P.M.

ST. LOUIS
W. G. Lee, 4710 Delor St., Tel: FL 8516.
First Wednesday, Meeting at 8:00 P.M., Engineer's Club of St. Louis.

TOLEDO
Morris L. Conner, 925½ Sherman St., Toledo, Ohio. Tel: MA 9403
Third Tuesday, Meeting at 8:00 P. M., Service Bldg., Toledo Edison Co.

TENNESSEE
N. M. Taylor, 16 Edgewood, Kingsport, Tenn. Tel: 3338J
No definite night, Dinner at 6:45 P.M., Meeting at 8:00 P.M., Hall's Dining Rm., Bristol Hwy., Kingsport.

TULSA
J. J. Fox, Phillips Petroleum Co., Bartlesville, Okla. Tel: 6600 Ext. 501.
First Monday, Meeting at 7:30 P.M., Engineering Bldg., Tulsa Univ.

TWIN CITIES
Alden Hine, c/o Pinkney & Hine, 552 Plymouth Bldg., Minneapolis 3, Minn. Tel.: Lincoln 0523.
Fourth Tuesday, Dinner at 6:30 P.M. Coffman Memorial Union, U. of Minn.

WASHINGTON
Raymond E. Miller, 20-224 Naval Ord. Lab., White Oak, Md. Tel: JU 7-6742
Third Monday, Meeting at 8:00 P.M., P. E. P. Co. Auditorium.

WAYNE COUNTY
Robert Karr, 2455 Biddle Ave., Wyandotte, Michigan. Tel. 0167J
Third Monday, Meeting at 8:00 P.M., Larson's Cafe, Lincoln Park, Mich.

WILMINGTON
J. E. Charsha, Jr., Hammel-Dahl Co., 1000 Washington St., Wilmington 11, Del. Tel: 2-6694
Third Tuesday, Meeting at 8:00 P.M. Harlan Public School, Wilm.

Special Notice

At the meeting of the Executive Committee held in Pittsburgh March 30-31, a recommendation was received from the Committee on Society Structure and Planning that the Society immediately employ a full-time Manager capable of taking over full responsibility for operating the National Headquarters and directing all the work pertaining thereto. The Executive Committee accepted this recommendation.

This step has been in contemplation for some time. Secretary Rimbach has been carrying a double load in his two capacities as Executive Secretary and Exhibit Manager, and the rapidly expanding work load of the National office makes it impossible for him to continue to serve in this dual capacity. It should be pointed out also that he has never received any remuneration for his work as Executive Secretary, and the Society cannot reasonably expect him to continue to do so indefinitely. He has repeatedly offered to do everything in his power to enable the Society to take care of this situation, and has recently stated that he will not ask the Society to take unduly hasty measures to relieve him of the double burden he is now carrying, but that he cannot continue indefinitely under the present circumstances.

Since this involves a radical change in Society operation, the Executive Committee feels that its impact on every aspect of Society affairs should be considered carefully. It is, therefore, engaged at present in a review of all phases of Society structure and operation, and has asked the Committee on Society Structure and Planning to amplify its original recommendations to include a definite statement of the duties and necessary qualifications of a Manager. The Executive Committee hopes to be able to submit a complete recommendation and plan of operation to the Board of Directors at the Annual Meeting in September.

- J. B. McMahon,
President

Factors in Precise Control of Liquid Flow

By ALLAN R. CATHERON*

Abstract. This paper describes some studies of liquid flow and its control made in response to the increasing demand for better flow control. New measuring elements, developed to meet this demand, pick up higher frequency signals than previously apparent, with some being useful for flow control and some being considered as "noise."†

The time constant of a flow system was known to be very short, and the control system components were speeded up to match them more nearly to the process, and to the new fast elements. Comparisons are made in the paper between these time constants, and the relationships required for stability are discussed. An attempt has been made to determine the source of the "noise," to minimize it at its origin, and to study its effects on the control system.

The relative effects of transmission lines and valve operators in a fast control system were studied.

Control of liquid flow rates is a problem that has been with us for many years. It has formed one of the most active and successful fields of instrumentation, and the development of equipment has in general kept pace with the demands of industry. However, recently there have been a small number of cases in which existing equipment has not been completely satisfactory, resulting in a demand by industry for better control. The demand stems from installations involving long pneumatic transmission lines, and processes which require exceptionally fast control system response if the flow rate is to be kept within the desired bounds.

In recognition of this demand, The Foxboro Company instituted a project of study of the characteristics of flow systems and the associated measurement and control equipment. The primary object of this study is to improve the quality of control. The direct meaning of this better control to industry is reduction of the amount of off-standard product and fewer production delays and upsets. Such improvements result from holding deviation to a minimum in both extent and duration.

An earlier paper[1] by Mead Bradner of The Foxboro Company discussed the lag characteristics of pneumatic transmission lines in detail. The present paper takes up some of the flow process characteristics and their effect on control. In addition, it shows how it is possible to modify and match the control system components to the process and to each other so as to meet any present industrial requirements.

Results Summarized

(1) Notwithstanding popular concepts, pneumatic transmission lines in a conventional flow-rate control system do not contribute the major lags. Assuming a high-speed differential-pressure transmitter, it is instead the valve motor that is the slowest unit to respond. When the valve motor is connected to the end of a transmission line the lag is greatly increased due to the flow of air required to move the motor. This gives an erroneous impression as to the lag of the line which latter only can be defined with a negligible volume termination (such as a receiver bellows).

The following series of illustrations are intended to demonstrate the effects of various system components. Each figure shows (a) a bar chart which is a summation of the time constants of system components, and (b) a typical flow rate record made during the recovery from a 10 percent load upset. The flow system was the same for all tests, in which the high-speed differential-pressure transmitter was used.

Fig. 1 represents the action with a nominal length of transmission line (a 100-foot pair) and a direct-connected valve motor. Note how much of the time-constant total comes from the motor and its loading effect on the transmission line.

The decrease of over six seconds in the sum of the time constants and the improvement in control response resulting from removal of the transmission lines appears in Fig. 2. The valve motor is still the major offender.

Figs. 3 and 4 show the time constant totals and response records for the same two arrangements except with an added device that materially reduces the time constant of the valve motor and at the same time takes its large volume load off the control relay and transmisison line. Here the time constants have been very materially reduced, and the control response correspondingly improved.

The effect of the removal of the transmission line now amounts to slightly over one second, which bears out the point that *it is the large volume on the end of the transmission line that is most harmful, and not the line itself.* Fig. 6, a replot of Figs. 2 and 3, bears out the fact that the lags of the process, high-speed transmitter, and controller have relatively little effect on the performance and that the apparent effect of the transmission line can be reduced to a negligible quantity by proper treatment of the valve operator. Thus it is obvious that the high-speed system with transmisison line is at least equivalent to conventional systems *without* transmission lines.

(2) Use of damping in a flow recorder-controller combination to obtain a smooth record can result in loss of control quality. A noisy signal has little effect on the action of a standard flow controller, but the loss of short-term information resulting from damping out the noise may seriously affect the ability of the controller to hold the process within particularly close limits under sudden changes of load. This is shown by the comparison in Fig. 5 of a damped-control record and the corresponding actual flow, as measured by the high-speed differential transmitter at the orifice.

(3) The one effect that the noise seems to have on control action is to require a wider proportional band for system stability. However, use of the high-speed differential-pressure transmitter and high-speed valve actuator permits the use of fast reset rates (increased in the order of 50 times) so that recovery times are reduced materially in comparison to those of slower systems.

These three observations are generalizations that can be made from the results of this work to date. Further study, especially in field tests, should help toward more complete evaluation of this new technique.

Historical Background

It has been generally known for a long time that flow processes are extremely rapid in response, but little quantitative data existed. Until recently, the majority of industrial flow measurements were made with a mercury manometer type of instrument on the primary differential elements, and where transmission was necessary, the pen or pointer motion was connected to a pneumatic transmitter. Mercury manometers form natural damping devices with a high degree of effectiveness, and thus they are ideal for straight recording applications, especially where the chart record is to be integrated.

The more common present-day practice is to use a high-speed force-balance differential-pressure transmitter, which converts the differential directly into an air-pressure signal without any intermediate indicating or recording mechanisms. Because such a device is inherently fast in response, its use results in the accurate transmission of higher frequency signals (or signal changes with steeper wavefronts) than has been previously possible.

The increasing industrial use of the faster signalling means has coincided with an industry demand for closer control, emphasizing the need for a complete re-examination of the flow control problem. The rapid fluctuations caused the recording pen to paint a band on the chart, and a means of reducing this band width seemed necessary. This was accomplished by inserting a restriction into the receiver end of the pneumatic transmission line. In systems requiring particularly fast control, it is necessary to separate the

THE AUTHOR

Allan R. Catheron, Research Engineer, The Foxboro Company, Foxboro, Mass., received his B.S. in Mechanical Engineering (Aeronautics) from Worcester Polytechnic Institute in 1936. Mr. Catheron has been employed by The Foxboro Company since 1936 in various engineering and research capacities.

*Research Engineer, The Foxboro Company, Foxboro, Mass.

†In this paper, the term "noise" is used to describe secondary disturbance of the system, cyclic or random, occurring at frequencies too high for effective control action.

NOTE: Presented before the Fifth Annual Convention of the Instrument Society of America, at Buffalo, N. Y., Sept. 18-22, 1950.

Statements and opinions expressed in these articles are those of the authors and not necessarily those of the Society.

(1) "Pneumatic Transmission Lag" by Mead Bradner, Instruments, Vol. 22, No. 7, pp. 618-625, July, 1949.

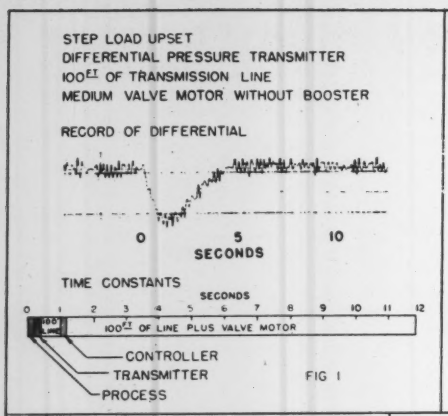

FIG 1

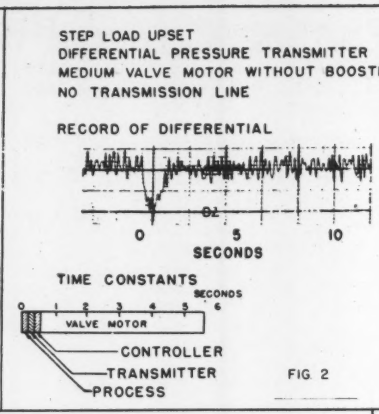

FIG. 2

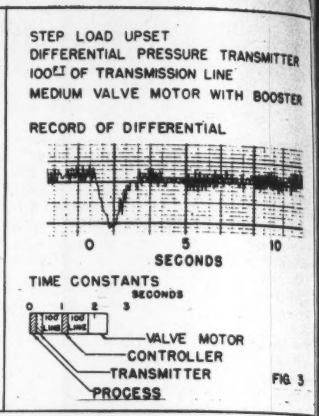

FIG. 3

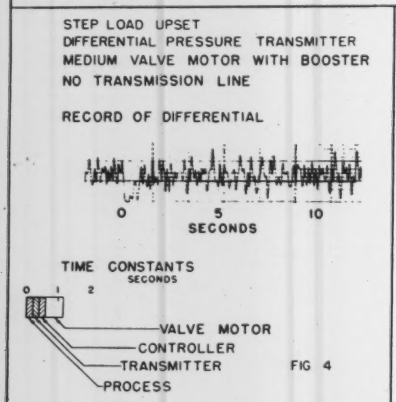

FIG 4

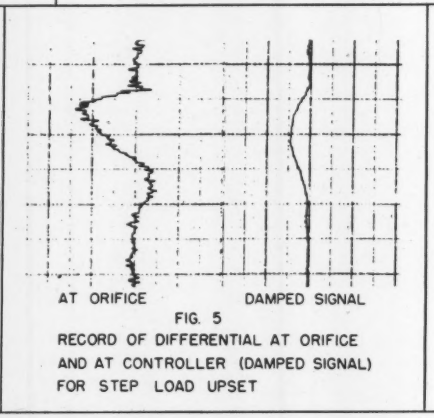

FIG. 5
RECORD OF DIFFERENTIAL AT ORIFICE AND AT CONTROLLER (DAMPED SIGNAL) FOR STEP LOAD UPSET

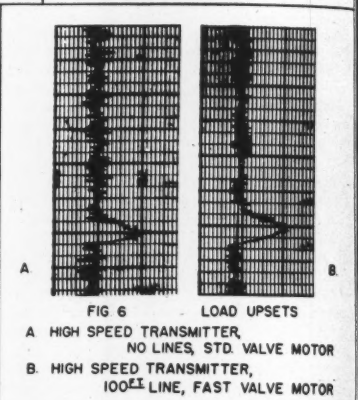

FIG 6 LOAD UPSETS
A. HIGH SPEED TRANSMITTER, NO LINES, STD. VALVE MOTOR
B. HIGH SPEED TRANSMITTER, 100 FT LINE, FAST VALVE MOTOR

record from the controller so that the necessary damping can be applied to the recording element while the controller is left undamped.

Experimental Procedure

The liquid flow system for these tests may be described as a piece of two-inch pipe with water flowing through it. The supply of water ordinarily comes from a storage tank (the driver tank of Fig. 13) in which the water is put under a controlled static head of air pressure to induce the flow. This feature was included in the system so that the supply to the line could be isolated from the line itself, and very accurate control of the pressure head obtained. It was used in the majority of tests because of the standardization of conditions that it afforded.

Granted that pumping directly into the line is a common industrial practice, it was felt that the change in method of supply would not materially affect the data. This was checked by duplicate operation of the system in pairs of upsets with only the method of supply changed, and satisfactory evidence obtained that the test results in the recovery studies were affected only by the line and control system characteristics, and not by the manner in which the line was supplied. Fig. 7 shows the pair of flow records with the greatest difference found during this check. All data used in this paper that involves transmission lines was taken with lines of 0.188-inch I.D. (nominal ¼-inch) copper tubing. More details are given in Appendix A.

For each combination of primary element, valve, valve actuator, and transmission line length, a series of records were run with various proportional band and reset adjustments. The optimum adjustments were determined by selecting the set that gave the minimum recovery time (or area under recovery curve) within the limitation of one overshoot. The recovery time under these conditions has been called the *"optimum recovery time"*.

Discussion

There is no question that a signal free of higher frequency components makes the best looking record, although perhaps at a sacrifice of short-term information.

Undoubtedly the most basic and, theoretically, possibly the best approach is to design the flow system to have a minimum of disturbance, but attempts to do this have been unsuccessful so far. Therefore, it is to be expected that it will be necessary to deal with a noisy signal.

The simplest damping means, and the one presently in use, is to put a restriction in the pneumatic transmission line at the receiver end. Since the desire for damping at a recorder-controller seems to be based on the smoother record resulting, the present trend to separation of record and control frees the controller from the lags imposed thereby. Generally, the performance of the control system is better on an undamped signal. There are, however, special cases (e.g., flow from reciprocating pumps) where damping improves control of the system.

In any analysis of the operation of a control system, the evaluation of the time constants of the system components is an important part. The fastest control is usually the best control, and

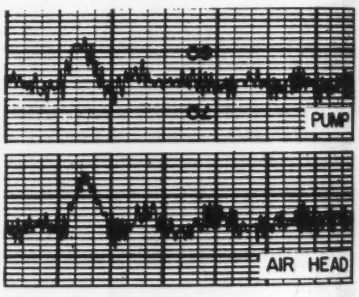

Fig. 7. Record of differential for load upset with two types of supply.

really fast control can only be obtained by going through the system and stepping up the responses, unit by unit. It is logical to begin with the slowest unit, which is the valve actuator.

In testing the fast units of the system, particularly, limitations of sensing and recording equipment put the figures in ranges rather than at specific values, but it is felt that the ranges are narrow enough to provide useful data.

For example, the time constant (63.2 percent value) of the experimental flow system using a long flow line, plus the high-speed pneumatic differential-pressure transmitter, about 10 feet of ¼-inch line and a conventional strip-chart recorder, is less than 0.5 seconds. In contrast, the same system except for a mercury differential meter with a transmitter shows a time constant in the order of 10 seconds. Attempts to measure the exact time constant of the flow system alone have

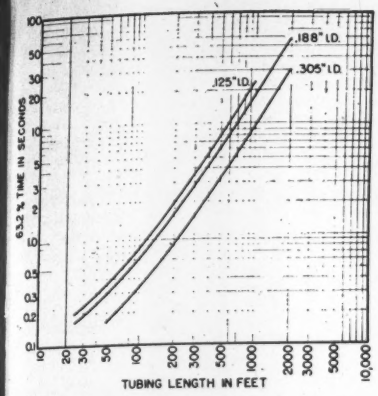

Fig. 8. Step Upset (3-15 psi.). Time constants for infinite capacity source and a number of lines (bellows terminated) are shown.

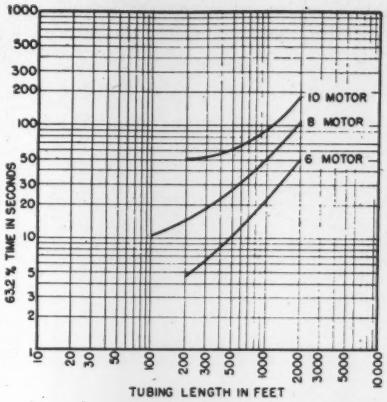

Fig. 9. Step Upset (3-15 psi.). Time constants are shown for infinite capacity source with "Stabiflo" valve-motor terminations, and 0.188-in. tubing.

failed due to limitations of measuring equipment, but a figure of 0.1 second is indicated.

The time constants of pneumatic transmission lines are directly dependent upon the length of line. With a small volume termination on the line, the effect of line size is relatively minor. Fig. 8 shows the time constants for an infinite capacity source and a number of line sizes. In general, they may be said to go up to 6 seconds for 500 feet of line, at approximately 1¼ seconds per hundred feet, assuming a small volume termination such as the bellows of a valve positioner, or of a receiver element. If, however, there is a valve motor at the receiving end of the line the corresponding figures reach 10 to 60 seconds, depending on the size of the motor, again with an infinite supply source. Obviously, the practical addition to the time constant from a valve motor directly on the line will be at least as large as shown here.

The "time constants" used throughout this paper are taken from the 63.2 percent point on the response curves, even when the curves do not correspond to the classical single-capacity response. This is particularly true in the case of valve motors, with or without boosters. The value is used in this way because it is the best simple approximate definition of response speed that will permit summations as in Figs. 1 through 4.

The controller mechanism itself has a proportional response speed which is representative of its time constant. This is on the order of 0.2 seconds, as determined in the course of reset rate tests. Thus the process, element, high-speed differential-pressure transmitter and controller together have a combined time constant in the order of 1 second. All the major lags are primarily in the valve actuating means. Here, then, is the point where the greatest improvement can be made in the development of a faster control system. A diaphragm motor without any aiding means is definitely slow by itself, and it is even worse when directly on the end of a transmission line. The friction effect of the tubing restricts the flow of air to the motor, making this lag serious. Fig. 9 illustrates this for an infinite air source (compare with Fig. 8). Increased line size and/or pressure provide only a partial correction.

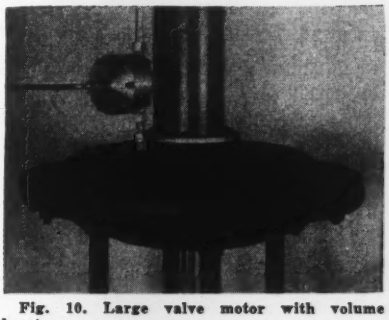

Fig. 10. Large valve motor with volume booster.

By introducing ahead of the valve a large capacity volume booster (20 cfm. free flow) a small valve motor requiring 4 seconds for full stroke with a conventional supply can be given a full stroke time of less than a second, while a large motor with full stroke time of 23 seconds, is brought to less than 3 seconds for the same stroke. (Fig. 10 shows such a booster mounted on a large valve motor.)

Fig. 11 shows the actual result of this treatment in a control system using a small valve motor. (Reference will be made frequently to small, medium, and large valve motors, and they are defined in Table I by several characteristics).

TABLE I—Valve-motor Characteristics

Nominal Size	*Small*	*Medium*	*Large*	*Very Large*
Stroke-inches	¾	1⅛	1¾	3
Motor diameter inches	10	15	19	21
Average effective area sq. in.	38	72	120	230
Zero stroke vol. cu. in.	22	105	135	....
Full stroke vol. cu. in.	57	200	387	1296
Conventional full stroke time-seconds	4	10	23	50
Full stroke time with booster-seconds	0.3	0.8	2.3	4.5
Foxboro valve motor number	6	8	10	....

When a standard valve positioner is added to the motor and valve assembly, the major improvement lies in the small and constant terminal volume that it puts on the line. The effect of this begins to be appreciable only after the line length passes 50 feet.

The increase in speed of operation of the various system components that is necessary to match the rapid response of a flow process has been covered in detail, and an idea of the response speed of the complete system has been established. There is one change in the action of a standard flow controller that must be made before it can be said to match the rest of the system, and that is to speed up the reset rate. For example, the Foxboro M/40 Controller is presently produced with a reset adjustment scale reading from 0.1 to 50 minutes per repeat (6 to 3000 seconds). A modified version of this

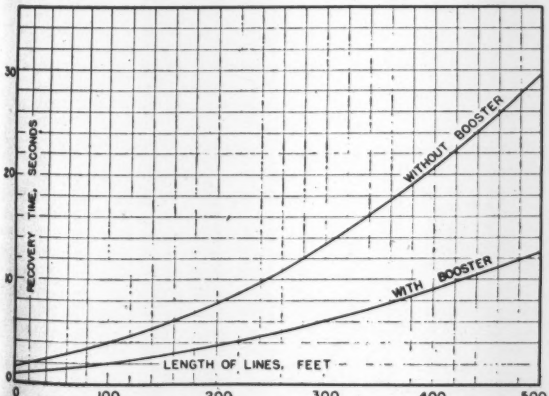

Fig. 11. Optimum recovery time for various lengths of transmission lines using small valve motor, with and without booster.

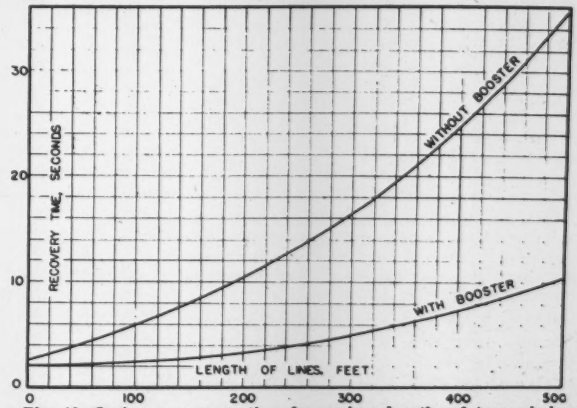

Fig. 12. Optimum recovery time for various lengths of transmission lines using medium valve motor, with and without booster.

instrument was used for almost all the test work on this project, the one change being to reduce the reset time to a range of 0.3 to 31 *seconds* per repeat. The proportional band adjustment mechanism was not changed. (Optimum adjustment ranged from 200 percent upward in proportional band with reset times often as fast as 0.5 seconds.)

These faster reset rates were particularly important since, as has already been pointed out, it is necessary to operate with wider proportional bands when the noisy signal is fed directly to the controller. The faster reset rates more than compensate for this proportional band widening and thereby enable faster, better control with the undamped signal. There is thus no valid objection to the wide proportional band.

The speeding up of the valve actuating rate is approaching the point where the valve motor time constant becomes a secondary lag. Because of this low time constant, a considerable length of transmission line can be accommodated before the system recovery time becomes as great as that developed when a controller is directly attached to a valve motor. This is illustrated graphically in Fig. 12.

Conclusion

The preparation of this paper has not concluded the work of the project, but only a phase of it. Correlated test results have led to the following conclusions:

(1) Liquid flow processes are extremely fast and vastly improved control can be obtained by speeding up the responses of the control system components.

(2) The slowest elements have been the mercury meter and the diaphragm-valve motor. On processes requiring fast control, mercury meters are gradually being replaced in the field by the far faster high-speed differential-pressure transmitter. The use of a special booster to speed up the valve has been covered in this paper.

(3) It was shown that the dominant lags formerly attributed to the transmission lines are actually caused by the volume of the valve motors in which the lines terminate. This fact minimizes the importance of line length in choosing the best place to locate control equipment.

(4) The functional separation of control and recording is desirable. Damping of the transmitted noise is necessary to obtain a clear record. An undamped high-speed signal is essential for fast control.

(5) If there develops a demand for still faster control, it may be necessary to do something about the noise in the system since its relative effect becomes greater as the entire system becomes faster.

(6) The majority of flow-rate control problems are satisfactorily handled by the conventional equipment consisting of high-speed differential transmitter, transmission lines, standard controls and valve. For those cases requiring exceptionally fast control, the same equipment with the addition of a booster at the valve as described in this paper is the indicated approach.

Acknowledgments.—The author wishes to thank the many members of the staff of The Foxboro Company who assisted in the preparation of this paper, in particular, Mr. Charles J. Stukas, Mr. Charles J. Koester, and Mr. Stuart W. Sweet, who ran the tests and analyzed the data.

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Appendix A—Test Apparatus

The equipment was planned with the intent of setting up a liquid flow line the performance of which would be reasonably representative of industrial practice and experience, and at the same time permit constant conditions to be maintained and measured. Water was selected as the liquid.

On this basis, the line was set up with two-inch pipe, and the supply made sufficient for flows up to 60 gallons per minute (making velocities of 5 to 6 feet per second). Since there was a considerable interest in the effect of the moving mass of liquid in a long straight pipe, and it was necessary to locate the system in a room 40 by 30 feet, six-foot radius bends were used as the equivalent of straight line, and the system looped to afford a maximum length of 137 feet. The line is level throughout, except at the discharge point. The length can be reduced if desired, because the system is assembled with flanged joints which afford simple rearrangement of the sections and a minimum of irregularity in the inside surface. The arrangement also permits variation of the location, spacing, and order of primary element and valve. The line, together with the supply system and the instrumentation used, is shown in Fig. 13.

To provide a uniform, readily adjustable head for driving the water through a system, a horizontally-mounted cylindrical tank is attached to

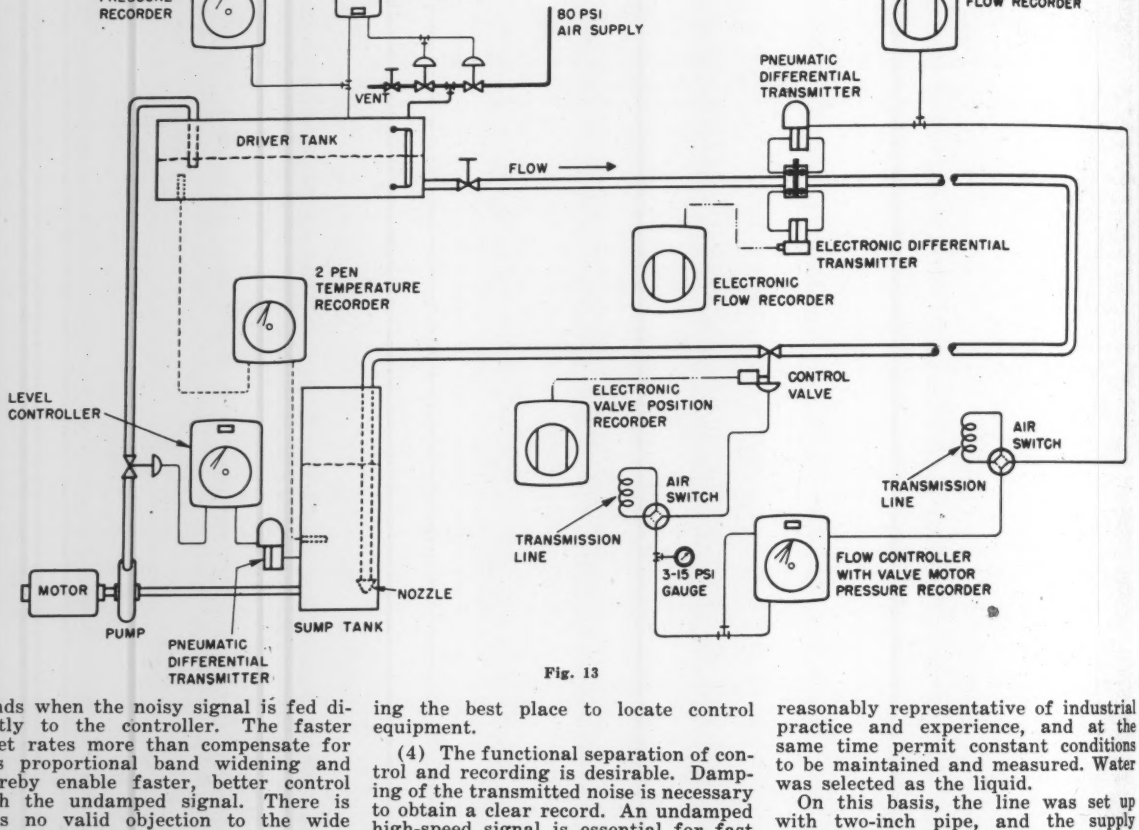

Fig. 13

the input end of the line. A pressure controller with duplex valves admits or vents air above the water in the tank to provide the desired static head. At the other end of the line, the water is discharged into a vertical cylindrical sump, from which it is picked up by a centrifugal pump and returned to the driver tank at the head of the line. A liquid-level control on the sump operates through a valve on the pump discharge to maintain the sump level constant, usually within an inch or two. Since the surface area of the water in the driver tank is about six times that of the sump, due to the different position, the actual head of water in the driver tank is held to a fraction of an inch, a negligible amount under ordinary test conditions.

In order to operate the system with the main control valve throttling the pump discharge directly, the more common industrial practice, the driver tank can be filled full of water and the air pressure head cut off. Then, with the sump-level control valve fixed wide open, the pump discharges directly to the line. This arrangement does not permit the independent control of upstream pressure afforded by the other supply connection.

As noted in the body of the paper, the two methods of supply were compared thoroughly to determine if there was any effect on the recovery data resulting from the change from one method to the other. The test was made by operating the system through a series of matched pairs of controls adjustments, upsets being made first with the air head on the supply and then by direct pumping. In every case, the recovery curves were either exactly matched or the recovery under direct pumping was slightly faster, which implies a system that is easier to control. Fig. 7 showed the poorest match, and Fig. 14 indicates a more typical comparison.

Results of early experimentation indicated that it was desirable to use a submerged discharge into the sump, with a nozzle at that point to maintain positive pressure, in all parts of the line (except at very low flows).

The system was instrumented to obtain the following information. In the driver and sump: records of driver pressure (head) and water temperature, and sump level and water temperature. The above instruments are all Foxboro round-chart recorders. Indicating gages permit a check of the pressure at the pump output and the driver pressure at the point where the latter is set. Sight gages afford indication of driver and sump levels.

In the flow line, the major part of the instrumentation is at the primary element. Whether orifice, nozzle, or venturi, two independent sets of differential taps are provided. One pair are connected through a Foxboro electronic differential pressure cell to a fast electronic recorder. This instrument is a Foxboro rectangular coordinate strip chart type with a pen speed of less than 0.8 seconds full scale and adjustable chart speed up to 12 inches a second; it is used to provide the picture of what is actually happening at the element. The other set of taps is connected to a Foxboro pneumatic differential transmitter. The output of this transmitter goes directly to a second strip-chart recorder, (with a pressure element) and it is also connected to a Foxboro M/40 round-chart recorder-controller.

This latter connection is made through an air switch that permits the insertion of a pneumatic transmission line if one is to be used. This, the basic controller of the system, and the one on which all adjustments are made, provides a record of the measured variable as the controller sees it, after transmission lines, damping restrictions, etc., and a record of the valve-motor pressure as determined by the controller. The output pressure signal from the controller is run to the valve through another air switch for the insertion of transmission line.

A large indicating gage at the controller is a convenience to show valve-motor pressure from a distance, and it is so connected that either the controller

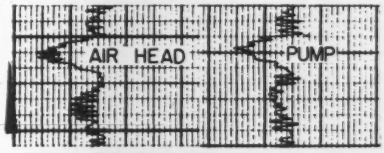

Fig. 14. Record of differential for load upset with two types of supply.

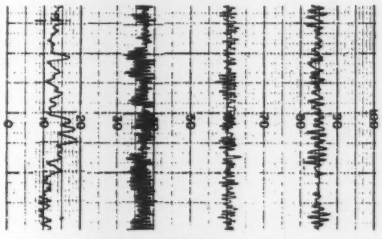

Fig. 15

output or that of an alternative manual control unit is indicated. A completely independent manual control has proven useful for experimental purposes.

At the valve, which may of course be equipped with positioning devices, booster relays, etc., a strain-bar spring coupled to the valve stem is connected to a third strip-chart recorder (again electronically operated) to give a record of actual valve position. It can readily be seen that this reading may not always correspond to the valve-motor pressure, especially under dynamic conditions.

The three strip-chart recorders and the group of round-chart recorders each have common chart-drive controls so that synchronized sets of records can be obtained.

For added indication or records as they may be required, the flow line is equipped with static pressure taps at a number of points, particularly in the valve flanges so that valve drops may be determined.

In addition to the air switches that permit rapid cutting in or out of pneumatic transmission lines between the transmitter and the controller and the controller and the valve, a patch board arrangement permits selection of lines from 50 to 2000 feet in length in either the ¼ or ⅜-inch tubing sizes.

Table II summarizes the records as generally made, according to their function in analysis.

TABLE II

I—Basic Input-output Standard for Process	
A. Differential	Electronic strip-chart recorders
B. Valve position	
II—Control System Data	
A. Pneumatic differential signal at transmitter	(strip chart)
B. Pneumatic differential signal at controller	(round chart)
C. Controller output, valve-motor pressure	(round chart)
III—Auxiliary System Data	
A. Driver tank pressure, or operating static head	(round chart)
B. Driver tank temperature	(round chart)
C. Sump level, indirectly driver level	(round chart)
D. Sump temperature	(round chart)

APPENDIX B—Comments on Noise

Actually, so little was known about the higher frequency signals, their source, and their real effect on the quality of control that the start of this study of flow-rate control found the problem of noise, what it was and did, and what to do about it, the first question to be examined.

It appears that the majority of flows measured with any means having a good high-frequency response show much noise or rapid fluctuation. Records were taken from a variety of industrial flow processes, and all showed similar noise patterns when the high-speed differential-pressure transmitter and fast strip-chart recorder were used. Fig. 15 shows three of these records with one taken on the test system. These records represent, from left to right, flow rates of: (1) bottoms from crude fractionating tower after centrifugal pump, a highly viscous fluid, (2) pulp mill green liquor after centrifugal pump, (3) the test system, and (4) sulfite acid to pulp digester after centrifugal pump.

This term "noise" has been applied to the higher frequency fluctuations, perhaps not too accurately in the communications sense of the word. Admittedly, the definition is on a distinctly sliding scale, for the lower limit of the noise spectrum is dependent upon its ability to influence the individual control system, while the upper limit is so far defined entirely by the recording equipment available.

Following are some disconnected observations that were made in the course of this study.

The nature of the noise seems to indicate that it is either the sum of a number of fairly high frequencies or a completely random fluctuation. The various types of measuring elements and recording equipment that were tried all had resonances that were excited by the noise, and therefore its exact nature was not determined.

In any given system, the amplitude of the noise is in approximate proportion to the rate of flow.

Presumably the noise is the result of turbulence at the various irregularities in the system, of which the control valve seems to add the most (as determined by substituting a section of pipe for the valve). The primary element, surprisingly enough, does not seem to add appreciably to the noise, as indicated by a change from orifice to venturi without alteration of the noise amplitude. The termination of the flow line in the sump,

however, seems to be very important, for the addition of a submerged choke termination reduced the noise very materially.

A small amount of air injected into the system will cause a large disturbance.

Time did not permit study of the effects of elbows, etc., instead of the long radius bends used, but it would be expected that they would add to the disturbance, probably in the form of more turbulent flow. Changes in line length and the relative positions of valve and primary element had little effect.

Using the system shown in Fig. 13, the noise amplitude was unchanged whether the pump was on or off, and, within the limited flows available, neither was it changed by supplying the system from the water mains, cutting out the whole pump and driver circuit entirely. If the driver tank were solid filled with water, and the pressurizing system closed off, so that in effect the pump discharged directly into the line (through a permanently open sump-level control valve), there was a distinct increase in the high-frequency amplitude, though little on the signal used for control.

The most important thing, of course, is the effect of this noise on the control of the system in which it occurs. As might be expected, it tends to make the controller somewhat less stable, and wider proportional bands are required to minimize the response to the fast random variations. Because of the increased speed of the control system, the use of short reset times prevents loss of recovery rate, the random variation being absorbed by the integrating action of the rate response.

Fluctuations of lower frequency can get through the controller to the valve, particularly in the case of close-coupled equipment. The higher frequencies are damped out by the valve and transmission lines.

All the above is based on the study of the inherent noise in the line, that is, the disturbance resulting from waves, reflections and turbulence in the flow system itself. These are the common conditions. Externally applied disturbances may well be large enough to disturb the system thoroughly and also require a considerable amount of damping for stability. They must be handled individually if the speed of control precludes using simple damping.

Recording Conductometer for Electrolytes*

By L. E. ASHMAN, R. S. COHEN, J. A. GLASS, H. R. STILLWELL and H. E. JONES†

ABSTRACT. The conductometer described was designed primarily for industrial applications. It will measure directly the specific conductance of electrolytes to an accuracy of at least 0.1 percent from 0.002 (ohm cm)$^{-1}$ (corresponding to about 0.015 N KCl) to high values which are limited by the polarizing characteristics of the liquid under test. For KCl the upper limit is about 0.04 (ohm cm)$^{-1}$ or 0.3 N, above which accuracy drops off due to drift in cell constant. The range is extendable to solutions of greater dilution by simple resistance changes in the circuit. Differential measurements can be continuously recorded to an accuracy of 0.03 percent. The full scale optimum sensitivity corresponds to a 3.3 percent change in conductivity, or in the usual industrial notation, a change in cell ratio from 1:1 to 1.033:1.

Significant features of the instrument are thermistor temperature compensation, operation at liquid pressures up to 150 psi., and high stability for extended periods of time. Measurements on aqueous solutions of KCl resulted in less than 0.1 percent drift during continuous operating periods of two weeks duration. Maximum peak to peak noise level corresponding to less than 0.017 percent change in conductivity.

For controlling the formulation of the latex feed streams in a GR-S rubber plant, electrical conductivity seemed to offer good possibilities as a control medium. A preliminary investigation, however, immediately accented the two main obstacles which have long been at least partially responsible for the relatively minor roll conductometry plays in the current industrial control picture: namely, the high negative temperature coefficient of electrolytes, and the tendency for cell constants to drift.

For most electrolytes, the temperature coefficient is approximately −2 percent per degree C., and unless good compensation is provided, small temperature fluctuations may overshadow the desired results. In the past, partially successful compensation has been achieved by immersing in the sample stream a reference cell containing a liquid with a similar specific conductance and temperature coefficient. The ratio of the cell resistance is then relatively independent of temperature, but the response time of such a system is rather slow.

In the present instrument, simpler and more satisfactory compensation has been obtained by replacing the reference cell with a thermistor[1,2] in series with, and shunted by, variable resistors. This method provides very rapid response, as well as effective temperature compensation over a wide temperature range.

The drift in cell constant which occurred with the dipping type electrodes (the only ones available which would withstand high pressures at the time this work was undertaken) was particularly bad. The turbulent flow patterns through this assembly with the accompanying high shear rates in the liquid, tended to break down some emulsion systems, and particularly in the case of latex, which coagulates readily, caused deposition of particles and sludge on the conducting surfaces. The ring electrode cells developed are rugged, withstand pressures up to 150 psi., and have uniform flow characteristics.

Cell Design

Since the resistance between electrodes of a conductometric cell is dependent upon the cell geometry as well as the electrolyte concentration, it is necessary to introduce a cell constant to convert resistance measurements to specific resistance (or the reciprocal, specific conductance). These are the values which would be measured by an idealized cell containing electrodes of one square centimeter in area and separated by a distance of one centimeter. To prevent electrolytic action in the cells, use of alternating current is essential, and while 60 cycles is apparently too low a frequency to entirely eliminate polarization errors, it is most convenient for industrial purposes and has given satisfactory results, espe-

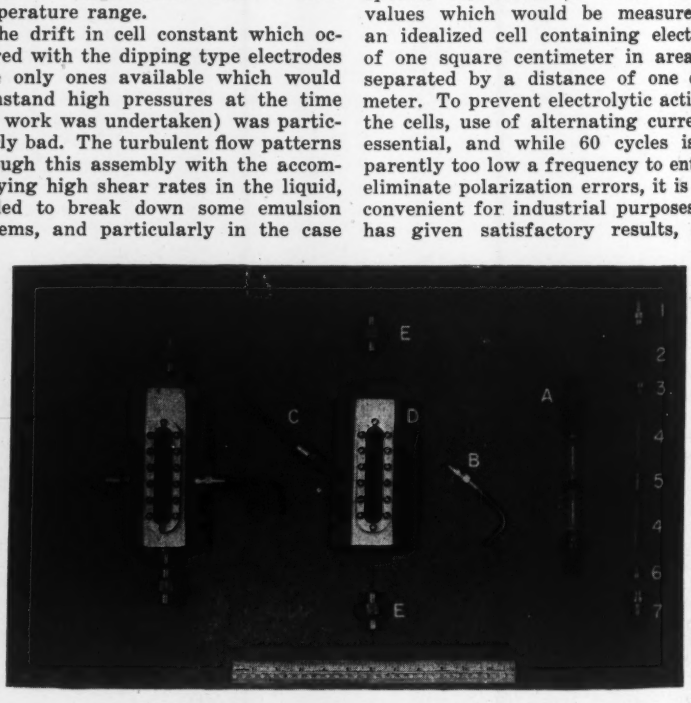

Fig. 1. Ring electrode conductivity cell.

*Contribution of multiple industrial fellowship of the Reconstruction Finance Corporation, Office of Rubber Reserve. Published by permission of the latter.

†Mellon Institute of Industrial Research, Pittsburgh, Penna.

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cially in differential measurements. By making the cell resistance high, errors introduced by polarization are further minimized.

Ring Cell Found Best for Application

The conductometric cells to be described were particularly designed for use in the synthetic rubber process. They are built to operate at pressures up to 150 psi. and are especially suited to emulsion systems. Experiments with a number of available cells seemed to indicate that non-uniform flow patterns, caused by the presence of the electrodes in the flowing emulsion stream, were responsible for erratic and inconsistent resistance readings. To eliminate this effect, the cell was designed to prevent unnecessary turbulence in the neighborhood of the electrodes. A ring electrode cell[3] (Fig. 1), consisting essentially of three metallic rings separated by two glass tubes, was found best suited for these requirements.

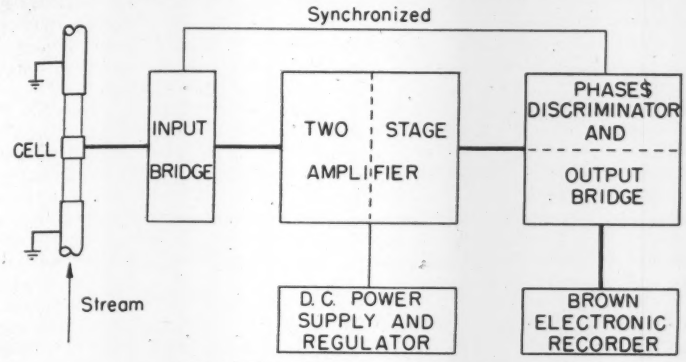

Fig. 2. Block diagram of conductometer.

The construction of this type of cell was a major problem, especially in view of the pressure requirements. To date three methods have been investigated with varying degrees of success, namely: (1) Platinum is deposited on the glass surface enabling the electrodes to be soldered directly to the platinum coating; (2) with Kovar electrodes and Corning 705A glass, the glass and metal are fused directly[4]; and (3) successive layers of platinum deposited on the glass are used as the electrodes in an arrangement similar to a ring electrode cell. This permits the use of a tube with no projections, except for the piercing of connecting wires to the electrodes.

The first method, since it allows a better selection of electrode materials, seems to provide the best cells from the standpoint of stability of operation. Unfortunately, however, it has not been possible to construct cells that will withstand any appreciable pressure without leaking or breaking.

The cells of method 3, the most recently developed, are now being used almost exclusively because of their superior stability and ease of construction. They are made by coating the electrode area with a suspension of platinum[5], and then burning off the carrier at a high temperature to leave an adherent metallic platinum coating on the cell wall. The connections to these electrodes were first made of Kovar (to insure a strong seal through the glass walls of the cell) but even this small amount of Kovar gave rise to corrosion difficulties and consequent changes in cell constant. It was finally found that if care was used in annealing, a fine platinum wire could be sealed successfully through the pyrex wall and the cells would still withstand pressures of 150 psi.

Cell Construction Method Selected.

The cells of method 2 are the most completely developed from an industrial viewpoint, and it was with these that the bulk of the experimental work was done.

The Kovar electrodes have been used with good results for measurements on many liquids, but corrosion sometimes occurs in the presence of strong salt solutions. At the right of Fig. 1, the cell components are shown before being fitted together. Components 3, 5, 6 are the Kovar electrodes. The metallic bellows 2 absorb mechanical or thermal strains which might otherwise crack the glass. The housing D, which provides electrical shielding and protection against breakage, is air tight and can be pressurized with an inert atmosphere. This not only equalizes the liquid pressure, but also reduces the explosion hazard if measurements are to be made in hazardous areas. External pipe fittings allow direct connection to a liquid stream.

Resistance measurements are made by applying a small potential between the center electrode and the grounded end electrodes. This arrangement is important because the electrolyte is usually grounded through the plant piping system, and unless electrode grounds are provided on both sides of the energized point, fluctuating ground potentials and resistances cause complete instability. The electrical path then consists of two columns of liquid in parallel.

Measuring and Recording

The method of measuring and recording the cell resistance is shown in the block diagram of Fig. 2. The input bridge, when balanced, provides a direct measure of the cell resistance. Any unbalance of the input bridge (caused by changes in the cell resistance) is amplified and passed into a phase discriminator, where the direction of unbalance is determined by synchronization of input and output circuits. The signal appearing on the recorder is a measure of the unbalance of the input bridge.

A more detailed discussion can best be followed by reference to the circuit diagrams of Figs. 3 and 4. The operation of the input bridge can be seen in Fig. 3. Transformer T_5 supplies two equal voltages 180 deg. out of phase, one of which is applied across R_4 and R_6 in series to ground and the other, across R_{11} and the cell. Since R_4 and R_6 are equal, the potential at b will be one-half the applied voltage to ground (R_{15} and R_{13} are so large that no appreciable current flows through them). Hence, if R_{11} is set equal to the cell resistance, the potential at point c will also be half the applied voltage.

Since R_6 and cell A are opposing legs of a bridge circuit which includes equal resistors R_{13} and R_{15}, the voltage at d will be 0. Should R_{11} differ from the cell resistance, an unbalance will appear between d and ground. This unbalance signal is amplified and applied to the grids of V_3 in the phase discriminator (Fig. 4). At this point the phase of the amplified signal is the same as it was at the grid of V_1, and since T_1 and T_2 are synchronized by the main power source, one plate of V_3 will be in phase with the signal and the other plate, 180 deg. out of phase.

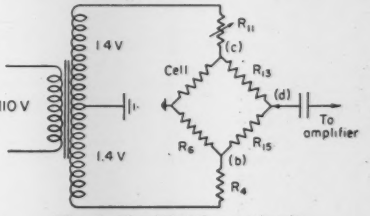

Fig. 3. Simplified input circuit.

Since the phase of the unbalance signal depends upon whether the cell resistance is greater or less than R_{11}, the side of V_3 having the greater plate current will determine the direction of unbalance. The voltage appearing at the cathodes of V_3 will consist of positive pulses corresponding to the positive cycles of the plate voltage. The two filter networks provide relatively smooth d-c. outputs to the recorder, which essentially measures the unbalance of two sections of V_3. The recorder reading is therefore a measure of the unbalance in the original bridge circuit, and is interpreted in terms of percent resistance change of the cell from the value of R_{11}. When the input bridge is balanced, the value of R_{11}, which may be read from a calibrated dial, is the same as the cell resistance.

The conductometer amplifier is standard, using resistance coupling and op-

erating class A. To attain the high stability of the present unit, it was necessary to use careful shielding throughout (Fig. 12) and to decouple the stages by C_7, C_8, R_{26}, and R_{27} (to prevent feed-back through the power supply).

The question may be raised as to why another amplifier, in addition to the one already present in the Brown recorder, is necessary. The primary purposes of this amplifier are to allow greater flexibility in the conductivity range covered and to provide high impedance coupling between the input bridge and the recorder.

In the final instrument the range may be set reproducibly for any predetermined coverage without the use of any auxiliary equipment for calibration. Another advantage lies in the highly filtered output of the amplifier, which will permit the recorder to be located at almost any distance from the input bridge without giving rise to line-capacitance and pick-up problems.

The d-c. power source is a conventional full-wave rectifier with a condenser input filter followed by a shunt-type electronic ripple regulator. A Sola regulator is used on the 115-volt, 60-cycle power source.

Performance of System

The accuracy of the conductometer is almost exclusively limited by the level to which fluctuations in cell constant can be reduced. By careful shielding, thermostating of the components, and regulation of critical supply voltages, electrical drift has been almost completely eliminated. Even over periods of two weeks, only 0.5 percent of full scale in the zero reading has been observed at the maximum operating sensitivity of 3.3 percent full scale (corresponding to a change in cell ratio from 1:033:1 to 1:1). The electrical noise at this sensitivity is less than one-half a chart division, or about 0.017 percent, which is well below disturbances caused by temperature changes of the solution and momentary fluctuations in cell constant.

Although cell resistance measurements can be made from 0 to 3000 ohms, the determination of the specific conductance from measurements below 500 ohms is not always reliable because of polarization electrodes and resultant drift in cell constant in this high conductivity range. This effect was greatly reduced when the change was made to the platinum electrode type cell, but it can not be entirely eliminated without employing frequencies of the order of 50 kc.

The present instrument with the Kovar electrode cell of Fig. 1, has a specific conductance range of about 0.002 (ohm cm)$^{-1}$ to 0.01 (ohm cm)$^{-1}$ with an absolute accuracy of one percent of the measured conductivity within that range. The lower specific conductance value is limited only by the size of R_9, R_{10}, and R_{11} and could be extended if necessary by increasing these resistors. Although specific conductance measurements are accurate to one percent when measured directly, changes in the liquid conductivity can be measured within 0.1 percent depending again upon the particular range of operation and with Kovar cells.

Fig. 5 represents direct measurements of the specific conductance of electrolytic solutions. Readings were made at each concentration by adjusting R_{11} to give a zero reading on the recorder. The liquids were continuously circulated, first passing through coils in a constant temperature bath and then through the cells.

Above a specific conductance of 0.01 (ohm cm)$^{-1}$, the data fall below that given in the literature. This apparently is due to significant polarization effects at the electrodes. The cell constant, previously determined to be 6.85 cm^{-1}, was used to convert the resistance measurements to specific conductance. The curve of Fig. 6 results from measurements on an emulsion system; in this case R_{11} remained fixed and the input bridge unbalance was indicated by the recorder. The chart sensitivity was adjusted to a value of 0.2 percent conductivity change per division.

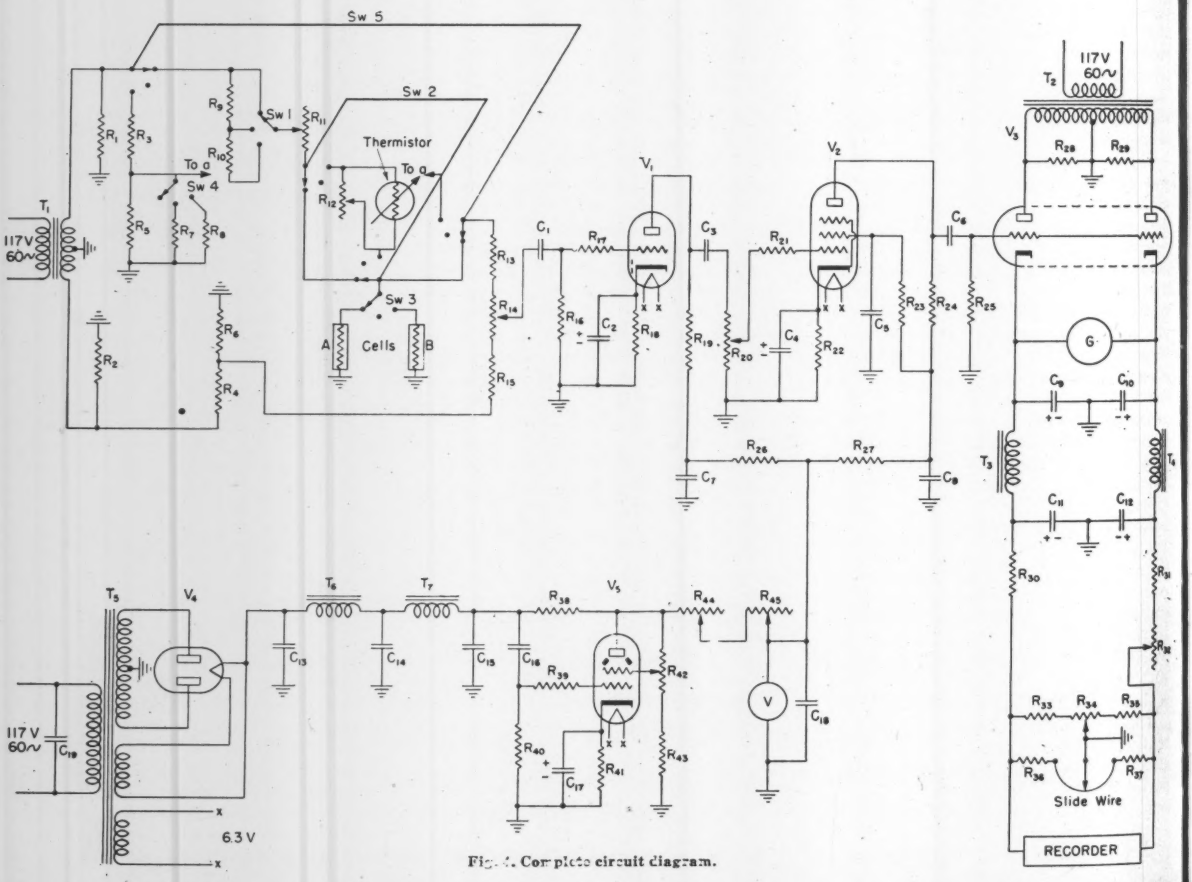

Fig. 4. Complete circuit diagram.

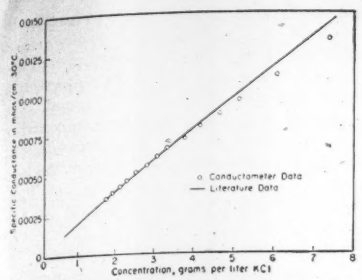

Fig. 5. Ring electrode conductometer measurements on aqueous solution of KCl.

With the more recent platinum type cells, a ten-fold increase in accuracy is possible, and measurements can be made on solutions of much higher concentration without encountering excessive polarization problems. For KCl, the upper conductivity limit is extended to 0.04 (ohm cm)$^{-1}$, or 0.3 N, as compared to 0.01 (ohm cm)$^{-1}$, or 0.075 N, with the Kovar cells. The absolute accuracy in the usable range is increased to 0.1 percent at the maximum operating sensitivity of 3.3 percent of full scale.

Temperature Compensation

Because of the excessive temperature coefficient of conductivity (about two percent per deg. C.), either temperature control of the liquid stream or good compensation for temperature changes is of primary concern, especially in industrial applications. In order to avoid the use of elaborate and expensive temperature control equipment, a thermistor has been incorporated in the input bridge to provide compensation. The characteristics of the thermistor used are depicted in Fig. 7. For a range of at least 10 C., this curve can be defined accurately by an equation of the form:

$$(1) \qquad R_T = R_0 e^{\frac{\alpha}{100}(T-T_0)}$$

where R_T is the thermistor resistance at a temperature T, and R_0 and α, the resistance and temperature coefficient (%/°C.) at a temperature T_0. Assuming $\alpha/100$ $(T-T_0)$ to be small compared to 1:

$$(2) \qquad R_T = R_0\left[1+\frac{\alpha}{100}(T-T_0)\right]$$

To justify this approximation $\alpha/100$ is determined by Fig. 7 at 30 C. to be −0.042. A comparison of equations (2) and (1) indicates that the error introduced by (2) will be within two percent for a 10 C. temperature range.

In order that a thermistor provide satisfactory temperature compensation, its thermal characteristics must match those of the conductivity cell. This may be arranged by means of the simple resistance network shown in Fig. 8, consisting of the thermistor in series with R_{11} and shunted by R_{12}.

The network resistance R_A is given by:

$$(3) \qquad R_A = R_{11} + \frac{R_T R_{12}}{R_T + R_{12}}$$

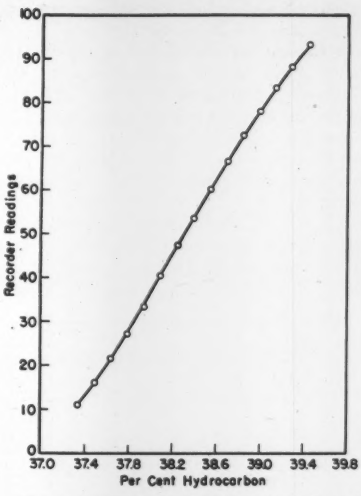

Fig. 6. Conductometer response to hydrocarbon variations in a soap-catalyst-water + methyl cyclohexane emulsion.

By substituting the value of R_T from (2) one obtains without appreciable error:

$$(4) \qquad R_A = \left[R_{11} + \frac{R_{12}R_0}{R_{12}+R_0}\right] + \frac{R_{12}R_0}{(R_{12}+R_0)^2}\,\frac{\alpha}{100}\,[T-T_0]$$

Similarly, for the conductivity cell, the resistance may be represented for a 10 C. temperature interval and with an error of less than one percent by:

$$(5) \qquad R_c = R_0^{\,1} + R_0^{\,1}\,\frac{\beta}{100}\,(T-T_0)$$

where $R_0^{\,1}$ is the cell resistance and β the temperature coefficient at some base temperature T_0. For maximum temperature compensation within the allowed temperature range, it is required that:

$$R_A = R_c$$

which implies that

$$R_0^{\,1} = R_{11} + \frac{R_{12}R_0}{R_{12}+R_0}$$

and

$$\beta R_0^{\,1} = \alpha\,\frac{R_{12}^2 R_0}{(R_{12}+R_0)^2}$$

Three useful relationships can now be found:

$$(6) \qquad R_0^{\,1} = R_c\left[1-\frac{\beta}{100}(T-T_0)\right]$$

$$(7) \qquad R_{11} = R_0^{\,1} - \gamma R_0$$

$$(8) \qquad R_{12} = \frac{\gamma R_0}{1-\gamma}$$

where

$$\gamma = \sqrt{\frac{\beta R_0^{\,1}}{\alpha R_0}}$$

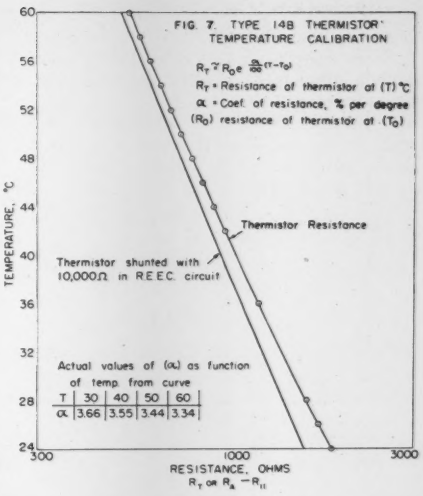
FIG. 7. TYPE 14B THERMISTOR TEMPERATURE CALIBRATION
$R_T = R_0 e^{\frac{\alpha}{100}(T-T_0)}$
R_T = Resistance of thermistor at (T) °C
α = Coef. of resistance, % per degree
(R_0) resistance of thermistor at (T_0)
Thermistor Resistance
Thermistor shunted with 10,000Ω in R.E.C. circuit
Actual values of (α) as function of temp. from curve
T | 30 | 40 | 50 | 60
α | 3.66 | 3.55 | 3.44 | 3.34
TEMPERATURE, °C
RESISTANCE, OHMS
R_T or $R_A - R_{11}$

By means of equations (6), (7), and (8), the settings for R_{11} and R_{12} can be found for any particular conductivity range in terms of the liquid, cell, and thermistor constants. The effectiveness of the compensation can best be seen by plotting exact values of R_A and R_c as functions of $(T-T_0)$. Typical values for constants are $\alpha = 4\%/C°$, $\beta = 2\%/C°$, $R_0 = 680$ ohms and $R_0^{\,1} = 1000$ ohms; from which $\gamma = 0.858$, $R_{11} = 416$ ohms, and $R_{12} = 4110$ ohms.

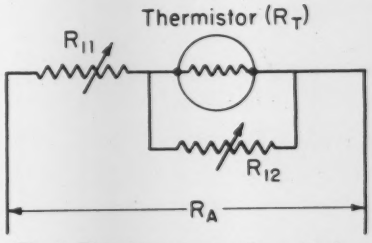

Fig. 8. Thermistor compensation network.

From equations (3) and (5), where R_T values are calculated from (1), R_A and R_c are plotted against temperature in Fig. 9. The fit is seen to be nearly perfect for about 6 C. above and below $T_0 = 30$ C. Beyond 6 C. the separation gradually becomes appreciable. Also the value of α will have changed slightly, introducing an additional error in compensation.

No noticeable drift has occurred as a result of changes in thermistor characteristics, nor has there been any deviation from the calibration curve (Fig. 7) after several months of use. An actual run is shown in Fig. 13. The small fluctuations of about four divisions in the middle of the chart are due to uncompensated changes in bath temperature, which was controlled to ± 0.03 C.

The large departure is the uncompensated effect of a temperature change from about 58 to 67 C., and would actually amount to about 5½ chart widths. This has been reduced to only ± 1 division by the compensator.

Nomograph for Compensation Settings

Since the foregoing calculations are rather difficult to handle, especially in the plant, a fairly simple nomograph has been developed to determine the settings of R_{11} and R_{12} for best compensation if the coefficient β of the electrolyte is known.

The resistance of the thermistor network (from equation 3) is:

$$R_A = R_{11} + \frac{R_T \quad R_{12}}{R_T + R_{12}}$$

Deriving:

$$\frac{\partial R_A}{\partial T} = \left(\frac{R_{12}}{R_{12} + R_T} \right)^2 \frac{\partial R_T}{\partial T}$$

Noting that:

$$R_A - R_{11} = \frac{R_{12} R_T}{R_{12} + R_T}$$

Then:

$$\frac{\partial R_A}{\partial T} = \left(\frac{R_A - R_{11}}{R_T} \right)^2 \frac{\partial R_T}{\partial T}$$

But:

$$\frac{\beta}{100} = \frac{\partial R_A}{R_0^1 \partial T}$$

Substituting:

$$\frac{\beta R_0^1}{100} = \left(\frac{R_A - R_{11}}{R_T} \right)^2 \frac{\partial R_T}{\partial T}$$

This will be a family of straight lines on logarithmic plot with a constant slope of 2, and parameter f (T), where f (T) =

$$\frac{\partial R_T}{\partial T} \quad \frac{1}{R_T^2}$$

These lines are shown on the left of Fig. 14 and are labeled for each temperature.

To take into account the β of the electrolyte, another family of lines may be plotted. From equation 5:

$$R_C = R_A = R_0^1 \left[1 + \beta (T_A - T_0) \right]$$

$$\beta R_0^1 = \frac{\beta R_A}{1 + \frac{\beta}{100} (T - T_0)}$$

This equation also represents a family of straight lines but with a slope of 45 deg. and parameter f (β, T) where f (β,T)

$$= \frac{\beta}{1 + \frac{\beta}{100} (T - T_0)}$$

These lines are plotted for several cases from the literature and also from actual determination on the instrument on the right of Fig. 14. It may be noted that most values of β given in the literature are for $T_0 = 18$ C.

To determine optimum values of R_{11} and R_{12} for given conditions, the instrument is balanced with R_{11}, R_{12} being set at highest value provided (10,000 ohms). The value of R_{11} is noted. The thermistor and R_{12} are short circuited with SW_3, and R_{11} is read again, giving R_A.

$R_A - R_{11}$ is computed, and referring to Fig. 9 (a plot of T against $R_A - R_{11}$ for a thermistor shunt resistance of 10,000 ohms), the temperature T of the electrolyte is found. Then referring to Fig. 14, R_A is located on the abscissa, and using the line for the appropriate β and T for the particular electrolyte and temperature, βR_0 is found. The value of $R_A - R_{11}$ for best temperature compensation can be read immediately, using the appropriate T line on the left.

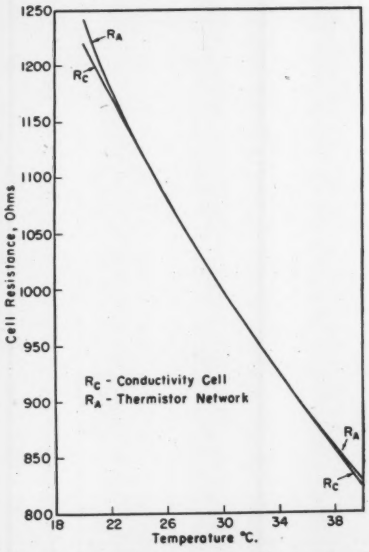

Fig. 9. Comparison of a thermistor network adjusted to match the thermal characteristics of an electrolyte.

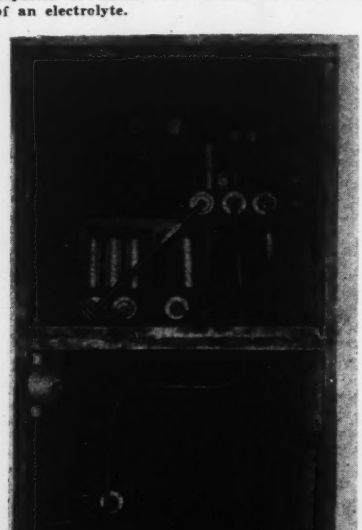

Fig. 10. Rear view of conductometer housing with panel removed.

The nomenclature used in the foregoing derivations is repeated as follows:

- T_0 —base temperature to which resistance measurements are referred
- T —actual temperature of cell
- R_0 —thermistor resistance at T_0
- R_T —thermistor resistance at T
- R_A —thermistor network resistance
- R_0^1—cell resistance at T_0
- R_c —cell resistance at T
- α —temperature coefficient of thermistor, %/°C.
- β —temperature coefficient of liquid, %/°C.

Mechanical Features

To make the conductometer suitable for plant installation, a number of features have been incorporated to insure

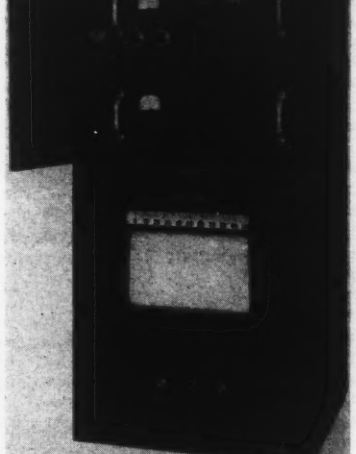

Fig. 11. Front view of conductometer.

Fig. 12. Amplifier panel for ring electrode conductometer.

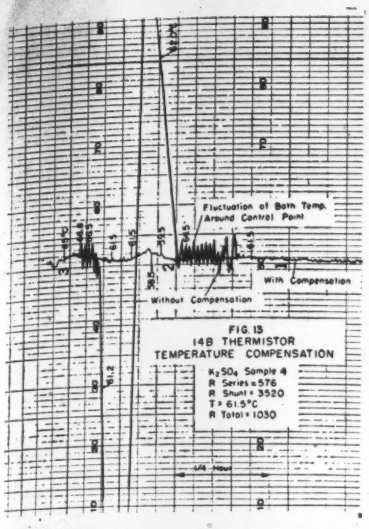

FIG. 13
14B THERMISTOR
TEMPERATURE COMPENSATION
K_2SO_4 Sample 4
R Series = 576
R Shunt = 3520
T = 61.5°C
R Total = 1030

maximum performance and to provide ease in servicing. The entire unit (Figs. 10 and 11), excluding the cells, is enclosed in an insulated steel housing. The input circuit amplifier and power supply (located in the upper part of cabinet in Fig. 10) are further protected from excessive ambient temperature effects by regulation of the air temperature in the cabinet. The temperature regulated air is circulated by the blower shown in the floor of the cabinet. All wiring interconnecting the units is enclosed in metal conduit and is connected to the units through lock-in plugs.

If required, the cells and the recorder may be located at remote distances (at least 100 feet) from the cabinet without interfering with the normal operation of the instrument. Much of the performance checking or trouble shooting can be accomplished by switches provided at the front panel (Fig. 11). Here the cell can be replaced by a fixed resistor in order to check amplifier stability and sensitivity exclusive of the cell. If the recorder is at a remote distance or if thought to be defective, a small galvanometer unit (not shown) can be plugged in at the side of the cabinet and necessary servicing or measurements made by reference to it.

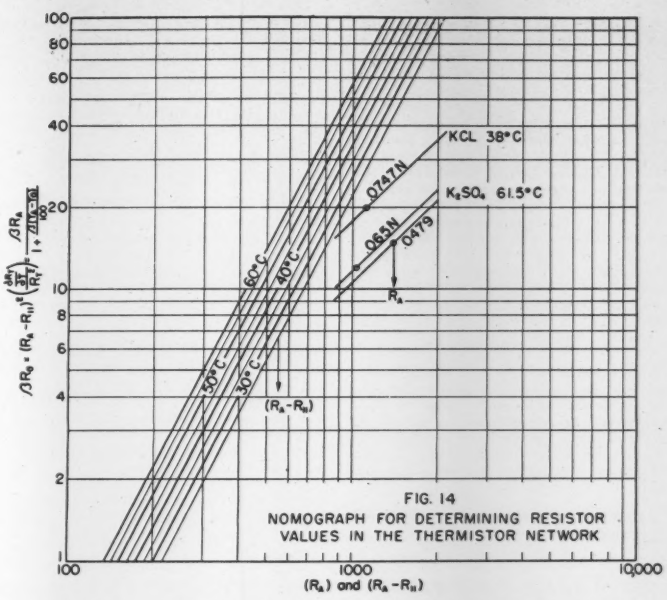

FIG. 14
NOMOGRAPH FOR DETERMINING RESISTOR VALUES IN THE THERMISTOR NETWORK

Acknowledgment.—Appreciation is expressed to J. R. Bowman for critical review of this paper; to G. H. Young and E. E. Stahly for general guidance.

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(2) Dowell, K. P., *Electrical Manufacturing*, August, 1948.

(3) Koppius, O. G., Private Communication.

(4) See in particular Bulletin 145, Stupakoff Ceramic and Manufacturing Company, Latrobe, Pennsylvania.

(5) Available from Hanovia Chemical and Manufacturing Company, Newark, New Jersey.

PARTS LIST (M = 1,000,000; K = 1,000)

R_1, R_2—5 ohms
R_3, R_5, R_4, R_9, R_{10}, R_6—1K ohms
R_7—49K ohms
R_8—200K ohms
R_{11}—1K ohms Helipot
R_{12}—10K ohms Helipot
R_{13}, R_{15}—2M ohms
R_{14}—10K ohms
R_{16}—750K ohms
R_{17}—110K ohms
R_{18}—5.1K ohms
R_{19}—.25M
R_{20}—1M ohms
R_{21}—56K ohms
R_{22}—2K ohms
R_{23}—1M ohms
R_{24}—240K ohms
R_{25}—1M ohms
R_{26}—20K ohms
R_{27}—7.5K ohms
R_{28}, R_{29}—15K ohms
R_{30}—2400 ohms
R_{31}—1500 ohms
R_{32}—1K ohms
R_{33}, R_{35}—120 ohms
R_{34}—10 ohms
R_{36}, R_{37}—500 ohms
R_{38}—25 ohms
R_{39}—2200 ohms
R_{40}—.510M ohms
R_{41}—400 ohms
R_{42}, R_{43}—10K ohms
R_{44}—5K ohms
R_{45}—1K ohms
C_1—0.5 ufd
C_2—50 ufd
C_3—0.5 ufd
C_4—50 ufd
C_5—4 ufd (oil)
C_6—0.5 ufd
C_7—4 ufd (oil)
C_8—4 ufd (oil)
C_9, C_{10}—50 ufd
C_{11}, C_{12}—50 ufd
C_{13}, C_{14}, C_{15}—4 ufd (oil)
C_{16}—2 ufd
C_{17}—25 ufd
V_1—6SQ7 metal
V_2—6SJ7 metal
V_3—6SN7 Gt
V_4—5U4G
V_5—6L6 Gt/G
V—0-500 v. d.c.
G—.5-0-.5 v. d.c.
Slidewire—300 ohms
T_1—1.25-0-1.25 v.
T_2—250-0-250 v.
T_3, T_4—chokes
T_5—6.3-5.0 v. 375-0-375
T_6, T_7—chokes

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Two Tentative Recommended Practices are now being distributed to the Society membership. These are *Flowmeter Installations Seal and Condensate Chambers, ISA RP*3.1, and *Uniform Face to Face Dimensions for Flanged Control Valve Bodies, ISA RP*4.1.

These Recommended Practices have been prepared as a part of the service of the Instrument Society of America toward a goal of uniformity in the field of instrumentation.

Concerning the first, *Flowmeter Installations Seal and Condensate Chambers, ISA RP*3.1: head-type fluid meter installations will be simplified considerably by the adoption of uniform practices in the fabrication of their seal and condensate chambers. This uniformity pertains to the over-all dimensions, general arrangement and location of connections, and the minimum sealing volume required by conventional meters. Pursuant to the adoption of the recommendations contained in this report, all similar types of seal and condensate chambers would be interchangeable with respect to installation dimensions, regardless of their source of supply.

Three methods of fabrication are shown, each illustrative of acceptable manufacturing practices. Two alternate types of condensate or seal chamber are illustrated, each of which may be fitted with any of the three end arrangements. The form of seal and condensate chamber advocated by this Recommended Practice is consistent with those available either from manufacturers or by field fabrication, and is currently used in a majority of installations.

This report was prepared by the ISA Sub-Committee on Fluid Meter Installation Practices, under the chairmanship of J. Johnston, Jr., E. I. duPont de Nemours & Co., Inc.

Dimensions covered in *ISA RP*4.1, *Uniform Face to Face Dimensions for Flanged Control Valve Bodies*, are the face to face body dimensions for flanged-end valves of both cast iron and steel through 600# flange ratings. Sizes included are 0.5 in. through .8 in. Only flanged valves which are in the category of diaphragm-actuated control valves of the plug type are included.

The dimensions recommended were developed by the majority of control valve manufacturers with the assistance of the National Steam Specialty Club, when it became known that the user industry was 100 percent in agreement that uniform face to face dimensions for control valves were desirable. The adoption of the dimensions treated in this Recommended Practice by all control valve manufacturers will allow piping design, where control valves are involved, without giving special consideration to the make of equipment to be used.

This accomplishment is a result of the joint effort of the National Steam Specialty Club and of the Instrument Society of America. This report was prepared by the ISA Sub-Committee on Control Valve and By-pass Manifolds, under the chairmanship of C. W. Bates, Humble Oil & Refining Co.

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Gas Measurement Committee Report*

By FRANK PARTRIDGE, Measurement Engineer, Southern California Gas Co.

THE Joint Gas Measurement Committee of the American Gas Association and the American Society of Mechanical Engineers is engaged in test work which may result in revision of our present methods of orifice meter measurement. In March 1951, a progress report on this project was published under the title "Interim Research Report No. 1 of the Joint AGA-ASME Committee on Orifice Meter Research" Project NGD-9, Natural Gas Department of the AGA. Copies are available from the American Gas Association, 420 Lexington Avenue, New York 17, N. Y. A brief summary of the results as they may affect measurement in California follows.

A. Interference tests.—These tests are to determine the required minimum length of pipe downstream from a globe valve or plug valve to an orifice meter. Results on the plug valve tests appeared to be nearly independent of: (1) the design of the plug valve; (2) whether the valve is in the meter run or the riser to the meter run; and (3) the rate of flow.

The curves in Fig. 1 show the minimum lengths of upstream meter tubes required in order to limit the effect of turbulence from an open plug valve to 0 percent and 0.5 percent, respectively, of the quantity of gas being measured. (No straightening vanes.)

Mitered ells in three-plane ell combination 16 P.D. upstream of plate indicated inaccuracies of 5 percent low using flange taps and no straightening vanes. Straightening vanes eliminated this effect. Welded ells without vanes located at 10 P.D. upstream had less than 0.5 percent effect on measurement.

The effect on measurement of open globe valves ahead of the orifice was found to be as follows:

	Effect on Measurement—%	
Beta	*Starts At*	*At 6 P.D.*
.8	24 P.D.	2 % High
.75	22 P.D.	1.7% High
.5	No effect as close as 6 P.D.	

B. Use of orifice fittings.—Present coefficients were obtained from tests performed with orifice plates between flanges. The use of orifice fittings had never been officially tested.

All three makes of orifice fittings have been tested using water at the Bureau of Standards Hydraulic Laboratory. Average values of results at all flow rates are shown in Fig. 2. The maximum effect found was on one fitting which produced a result which was 0.6 percent low with a Beta of 0.7. Fittings were tested at differentials of 15 and 50 inches of water and 15 inches of mercury (204 inches of water). One fitting leaked around the plate slightly at all differentials and another one leaked slightly at a differential of 15 inches of mercury.

C. Select-pipe versus bored or honed meter runs.—The growing use of bored meter runs has brought up the question of the accuracy of measurement under these conditions. In unofficial tests the majority of data agreed with the standard (select-pipe) run to less than ½ percent except at low differentials (2 in. or less). The bored-and-honed pipe consistently showed greater error than the bored pipe.

Six runs of various roughness including drawn aluminum and brass are being tested to determine whether or not roughness factors should be specified, and to determine if there are any errors introduced by the boring of meter runs. These tests will be conducted on 4-in. size runs only, and the flowing fluid will be water.

D. Orifice coefficients for large meters.—Considerable interest has been manifest in the use of orifice meters larger than the 16-in. maximum size included in the Coefficient Tables of the American Gas Association. The Joint AGA-ASME Gas Measurement Committee is investigating the feasibility of sponsoring a series of tests to check the flow constant (C) for large capacity meters in pipe sizes above the present maximum of 15 in. nominal pipe size, possibly up to 36 in. O.D., and on the tentative basis of 20 million cubic feet per hour maximum, at 500-1000 psig.

Under the present schedule it appears that the present AGA-ASME Gas Measurement Project will close late in 1951. It is reported that tests on pressure gradients near the orifice plate have been completed on 4- and 3-in. pipe. Data is not available as yet. Preliminary results on tests on pressure tap sizes indicate that the existing standards of ½-in. diameter taps on 4- and 8-in. meter runs are too large.

ASME Research Committee on Fluid Meters

A. Pressure-reducing valves.—At a recent meeting of the ASME Committee on Fluid Meters, the desirability of placing control valves on the discharge side of the metering orifice rather than on the inlet side was discussed. It was reported that one flowmeter company does not sanction the installation of control valves on the inlet side of any type of primary element. This immedi-

* Presented at the Spring meeting of the Technical Section of the Pacific Coast Gas Association, May 16-17, 1951, Bakersfield, Calif.

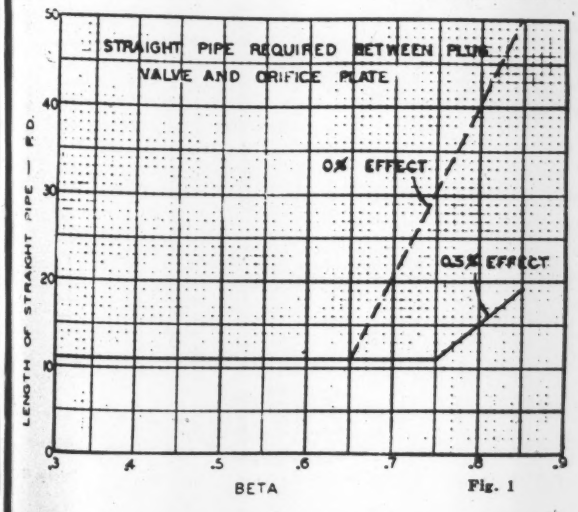

Fig. 1

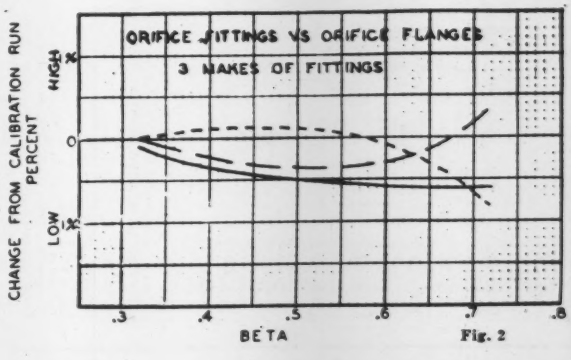

Fig. 2

ately raised the question as to the desirability of this procedure in gas measurement where the common practice is to place pressure-reducing valves on the inlet side of the orifice meter. The Committee decided that there did not seem to be any recognized errors produced by this practice. It did not appear appropriate to extend this limitation to the installation of orifice meters for gas measurement at the present time.

However, as data concerning the effect of a throttling valve ahead of an orifice meter is limited, it would appear desirable to consider this problem when designing or building new measuring stations.

B. Eccentric and segmental orifices.—Although the use of concentric orifices is almost universal in measuring gas in this area, there may be some special cases where the use of an eccentric or segmental orifice would be desirable. A special committee of the American Gas Association is engaged in testing work to determine data for computing coefficients for these orifices. A progress report has been published from which the following relationships were taken: The flow through a segmental orifice was from 0 to 7 percent higher than for a concentric orifice. The results from the eccentric orifice tests were more consistent. The flow was from 2.3 to 5.7 percent higher than that through a concentric orifice with the same diameter ratio. Results varied with the size and diameter ratio, Beta.

C. Supercompressibility.—A subcommittee of the ASME Special Research Committee has been investigating Flow Measurement at Extreme Conditions. One of the items studied is the effect of supercompressibility on gas measurement at high pressure. A questionnaire was sent to 30 operating companies throughout the country to determine the most common method of applying corrections for supercompressibility of gas.

It was found that all the companies used supercompressibility factors in at least part of their calculations. Corrections to each chart are made by 21 companies and corrections to monthly total volumes only are made by six companies. Three companies use a combination of the two methods. Factors are determined by calculation by 25, or 83 percent, of the companies, and by actual test by the remaining 17 percent. Of the 25 companies who calculate their supercompressibility factors, 20 use CNGA Tables. The other five use Natural Gasoline Association of America (NGAA) data.

Reports on the accuracy of results using the CNGA tables indicate that supercompressibility factors can be determined from CNGA data with an accuracy at least equivalent to that of the other factors used in orifice meter computations.

Experience with Large Orifice Meters

The Southern California Gas Company operates two 30-in. orifice meters to measure the gas entering the Los Angeles area from the Texas Pipe Line System.

Orifice coefficients for these meters are computed by using the empirical equations on Page 32 of CNGA Bulletin No. TS-353. The application of these equations to large orifice meters was discussed at the Transmission Conference held in 1950 (see PCGA *Proceedings*, Vol. 41, 1950, Page 190). In accordance with the recommendations in that report the flange taps on the 30-in meters are located 4 in. from the plate, which is approximately ⅛ pipe diameter.

The unaccounted-for gas figures for the section of the line downstream from the 30-in. meters give some idea of the measurement results. Due to line pack and draft, etc., the daily figures are somewhat erratic, but the monthly averages have been found to be more consistent:

February	0.05% gain
March	0.36% loss
April	0.06% loss

Experience has shown that it is important when operating large orifice meters to:

(1) Be extremely diligent in maintaining orifice meter gage, plate, connections, etc., in the very best condition and calibration.

(2) Select proper gage range and orifice plate size so that a readable record is made on the chart at all times.

Experience with the 30-in. meters as check meters has been very satisfactory, but they are not recommended for use as purchase or sales meters.

Work Plan of PCGA Gas Measurement Committee

Questionnaires, which invited questions or problems for consideration by the Gas Measurement Committee, were distributed at the last Transmission Conference. Most of the problems submitted concerned items being investigated by the Joint AGA-ASME Gas Measurement Committee. The question of possible revision of the CNGA

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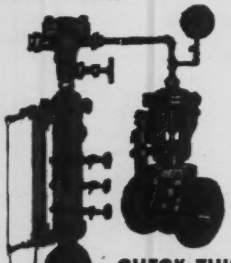

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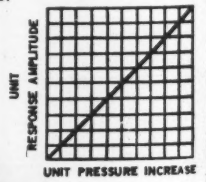

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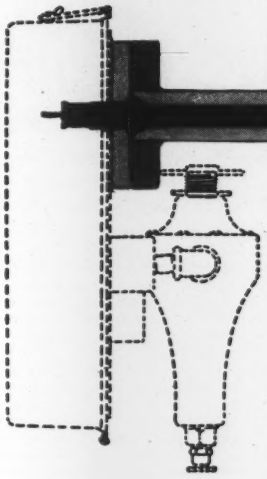

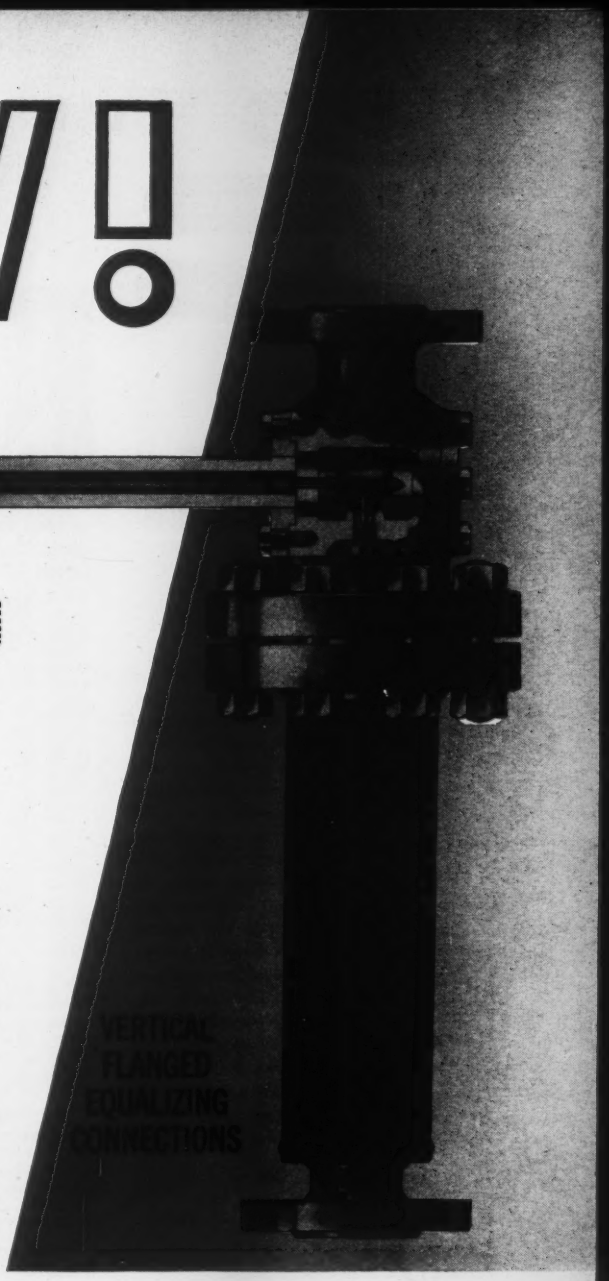

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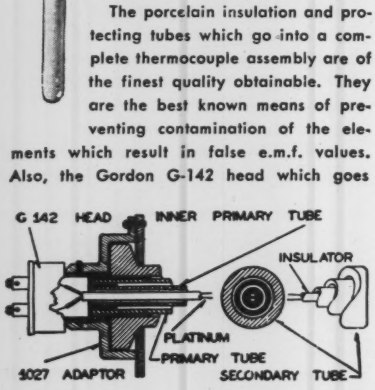

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significant-figure rule and the possibility of publishing supercompressibility factors for pressures of 0 to 5000 psig. in one bulletin have been submitted to, and are being studied by, the CNGA Gas Measurement Committee.

The suggestion on standardizing the face-to-face dimensions of orifice fittings has been called to the attention of the various fitting manufacturers.

It is felt that co-operation should be extended the American Gas Association and the American Society of Mechanical Engineers on their Gas Measurement Project and that any major change in present gas measurement procedures be postponed until a final AGA-ASME report is available.

Manufacturers' New Literature

In this department we report new literature pertaining to Instrumentation, received from the manufacturers. We urge readers to request ONLY those bulletins which will be of value to them. Use the Postage-free Order Card on Page 721.

Requests for literature FROM ABROAD should be made on company letterhead and mailed DIRECTLY to the manufacturers.

T-426 SEISMOGRAPHS. 4-page brochure illustrates and describes maker's low-cost "Series AR" seismographs for seismologist, meteorologist, experimenter, classroom, amateur and museum; discusses specifications, applications and installation requirements.—Sprengnether Instrument Co., 4567 Swan Ave., St. Louis 10, Mo.

T-427 TWO-PEN RECORDER. 8-page house organ, Vol. 10, No. 4 issue of "Modern Precision," features maker's new 2-pen "Speedomax" recorder for plotting 2 continuous curves simultaneously; includes articles on application of maker's products to TV, heat treating, annealing, oil line flow, kiln operation, telemetering, and combustion control.—Leeds & Northrup Co., 4097 Stenton Ave., Philadelphia 44, Penna.

T-428 OSCILLATORS. 64-page catalog illustrates and describes maker's electronic instruments and accessories for audio to microwave measurements including sweeping and marking oscillators, analyzers, attenuators, frequency meters, and reflectometers.—Kay Electric Co., Pine Brook, N. J.

T-429 PHASE-MEASUREMENT. 4-page Bulletin 950 illustrates and describes maker's "Model P-1061" instrument for measurement of phase difference at audio frequencies; discusses application, description, features, operation, principle, and specifications.—W. L. Maxon Corp., 460 W. 34 St., New York 1, N. Y.

T-430 REFRIGERATED BATH. 6-page brochure illustrates and describes 37 new laboratory appliances for chemistry, metallurgy and biology; includes refrigerated baths, synthetic sapphire mortar and pestle clamps, tachometer, electrograph, induction carbon apparatus, tilter tester, etc.—Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Penna.

T-431 BOILER FEED WATER CONTROL. 16-page Bulletin 489 features report of the installation of 3 boiler feed water control plants for the Georgia Power Co.; includes all significant data, photographs and diagrams.—Northern Equipment Div., Continental Foundry & Machine Co., Erie, Penna.

T-432 TIMING DEVICES. 8-page Catalog 323 illustrates and describes maker's electric timing devices including reset timers, internal timers, elapsed-time indicators, and fixed-cycle timers.—Haydon Manufacturing Co., Inc. Torrington, Conn.

T-433 MICROMETERS. 12-page Catalog 30 illustrates and describes maker's line of micrometers for all automatic uses.—Central Tool Co., Cranston 10, R. I.

T-434 AUTOMATIC COMPUTERS. 4-page bulletin and wiring diagram illustrates and describes maker's "Iconolog" series of automatic computers to reduce data from theodolite and other tracking film.—Genisco, 2233 Federal Ave., Los Angeles 64, Calif.

T-435 PROCESS CONTROL. 40-page house organ, Vol. 5, No. 2 issue of "Electronic Pneumatic Mechanical Instrumentation," features articles on application of maker's instruments to "atomic furnace" control, oil industry, citrus canning, germ control studies, spectrochemical analysis, galvanizing, plastics, etc., Industrial Div., Minneapolis-Honeywell Regulator Co., Wayne Ave., Philadelphia 44, Penna.

T-436 RESISTORS. 40-page Catalog RC8 illustrates and describes maker's line of electrical components including fixed and variable resistors, iron cores, line and slide switches, choke forms and capacitor units, and ceramic cores.—Electronic Components Div., Stackpole Carbon Co., St. Marys, Penna.

T-437 TEMPERATURE CONTROL. 4-page house organ, Vol. 10, No. 3 issue of "Wheelco Comments," discusses the application of maker's instruments to the clay processing and plywood molding industries.—Wheelco Instruments Co., Harrison & Peoria Sts., Chicago 7, Ill.

T-438 RHEOSTATS. 2-page house organ, March 1951 issue of "The Ohmite News," features articles on maker's field control rheostats and resistors covered by Specification JAN-R-26A.—Ohmite Manufacturing Co., 4835-41 Flourney St., Chicago 44, Ill.

T-439 VOLTMETER MULTIPLIER. 2-page Bulletin D-2 illustrates and describes maker's sealed voltmeter multipliers which meet JAN-R-29 specifications.—International Resistance Co., 401 N. Broad St., Philadelphia 8, Penna.

T-440 AIR LINE FILTER. 28-page booklet illustrates and describes maker's line of chemical laboratory glassware and interchangable ground glass joints and dealer line of general laboratory apparatus and chemicals; includes "Liqui-jector" air line filter, miniature pumps, condensers and adapters, pyrometer, and "Flur-etor" portable darkroom.—Scientific Glass Apparatus Co., Inc., 49 Ackerman St., Bloomfield, N. J.

T-441 ACOUSTIC SIGNAL. 8-page house organ, Vol. XXV, No. 10 issue of "The General Radio Experimenter," features discussion of "Intermodulation Distortion"; covers test conditions, harmonic distortion, intermodulation and other audio systems.—General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

T-442 PRESSURE SWITCHES. 2-page house organ, Vol. 1, No. 16, issue of "Cook Diaphlex Newsletter," illustrates and describes maker's miniature "Hydtrol" switch for aircraft and engine applications.—Cook Electric Co., 2700 N. Southport Ave., Chicago 14, Ill.

T-443 POSITIVE-ION ACCELERATORS. 4-page Bulletin H illustrates and describes maker's "Van de Graaff" 5.5-million-volt positive-ion accelerators for nuclear research.—High Voltage Engineering Corp., 7 University Road, Cambridge 38, Mass.

T-444 TESTING INSTRUMENTS. 32-page Bulletin C-50 illustrates and describes maker's testing instruments for petroleum industry; includes recording gravitometers, dead-weight gages, gas gravity balances, and vapor pressure bombs.—Refinery Supply Co., 621 E. 4 St., Tulsa 3, Okla.

T-445 RADIOACTIVITY DETECTOR. 12-page house organ, No. 33, March 1951 issue of "Tracerlog," illustrates and describes maker's "SU-8" pocket dosemeter and "SU-9" dosemeter charger includes description of 1951 summer course on Autoradiography at Oak Ridge Institute of Nuclear Studies.—Tracerlab, Inc., 130 High St., Boston 10, Mass.

T-446 RADIO-ELECTRONICS CATALOG. 132-page catalog of radio and electronic supplies for industry, university and research; includes absorption tester set, capacitors, fuses, oscilloscopes, and voltage-control equipment.—Sun Radio & Electronics Co., 122-124 Duane St., New York 7, N. Y.

T-447 PROCESS CONTROL. 8-page Bulletin 17-C illustrates and describes maker's instruments and controls for process industries; includes measurement and control components and diagrams of typical control systems.—Bailey Meter Co., 1050 Ivanhoe Road, Cleveland 10, Ohio.

T-448 LOAD CELL 2-page Bulletin 324 describes, illustrates and gives specifications for a new line of seven "Type U-1, SR-4" universal load cells with weighing capacity from 500 to 50,000 lbs. in tension and compression.—Baldwin-Lima-Hamilton Corp., Philadelphia 42, Pa.

T-449 SPECTROPHOTOMETER. 12-page house organ, No. 8 issue of "Laboratory Spotlight," illustrates and describes Beckman spectrophotometer and flame photometry attachment, Voland balances, Leitz microscopes and "Norelco" geiger counter x-ray spectrometer.—Harshaw Scientific Div., Harshaw Chemical Co., Cleveland 6, Ohio.

T-450 MONOCHROMATOR. 8-page house organ, Vol. 2, No. 1 issue of "Better Analysis," features illustrated article on "Micro-mulls," flame photometer and one-meter grating monochromator.—Baird Associates, Inc., 33 University Road, Cambridge 38, Mass.

T-451 ENGRAVER. 8-page bulletin illustrates and describes maker's heavy-duty bench-type "Model VE-3 Panto" engraver for engraving, electrical marking and acid etching; discusses size of work handled, equipment furnished, copy type available, etc.—H. P. Preis Engraving Machine Co., 651 State Highway 29, Hillside 5, N. J.

T-452 ELECTRONIC COUNTER. 4-page bulletin illustrates and describes maker's "Model 554 EPUT (events per unit time) meter ... of any mechanical, electrical or optical occurences that can be converted into

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Elementary Engineering Electronics by Andrew W. Kramer, 1945, cloth, 4½" x 8", 340 pages. Price $2.00.

Operation and Care of Circular-scale Instruments by James Spencer, 1949, cloth, 4½" x 8", 90 pages. Price $1.50.

The Engine Indicator—Its Design, Theory and Special Applications by K. J. DeJuhasz, 1934, cloth, 5½" x 8¼", 243 pages. Price $2.00.

Heat Inertia in Problems of Automatic Control of Temperature by Victor Broida, 1950, paper, 5¼" x 8¼", 61 pages. Price $1.00.

Applications of Industrial pH Controls by Allen L. Chaplin, 1950, cloth, 4½" x 8", 144 pages. Price $2.50.

Maintenance and Servicing of Electrical Instruments by James Spencer, Third Edition 1951, cloth, 4¾" x 8¼", 256 pages. Price $3.00.

Mechanical Measurements by Electrical Methods by Howard C. Roberts, Second Edition 1951, cloth, 4¾" x 8¼", 357 pages. Price $4.00.

A Romance in Research—The Life of C. F. Burgess by A. McQueen with a Technical Appendix by O. W. Storey, 1951, cloth, 6" x 9", 430 pages. Price $6.00.

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T-453 SPEED CHANGERS. 2-page Technical Data Sheet No. 7 illustrates and describes maker's "Series 7" zero-backlash miniature speed changers; discusses principle of operation.—Metron Instrument Co., 432 Lincoln St., Denver 9, Colo.

T-454 SWITCH. 2-page house organ, Vol. 7, No. 1 issue of "Uses Unlimited," discusses application of maker's switch units to radial-head face grinder.—Micro-Switch, Freeport, Ill.

T-455 ILLUMINATED MAGNIFIER. 4-page catalog illustrates and describes maker's "Flash-O-Lens" to aid in accurate inspection for industrial uses; battery and electric models available.—E. W. Pike & Co., 492 North Ave., Elizabeth 3, N. J.

T-456 COUNTING DEVICES. 8-page Catalog 53 illustrates and describes maker's line of "Silver King" and "Wizard" stroke and revolution counters.—Production Instrument Co., 710 Jackson Blvd., Chicago 6, Ill.

T-457 AMPLIFIER. 4-page Circular B-11 A illustrates and describes maker's "Model 101 Inductronic" d-c. amplifier; gives technical description, input conditions, mechanical design, accuracy, accessories, and specifications.—Western Electrical Instrument Corp., Newark 5, N. J.

T-458 SERVOUNIT. 2-page bulletin illustrates and describes maker's "Magnetorque" servo unit for use in computer circuitry and remote positioning devices requiring low torque; lists specifications.—Avion Instrument Corp., 121 E. 24th St., New York 10, N. Y.

T-459 TUBE SUBSTITUTION. 40-page manual contains quick references for critical radio and TV tubes; contains diagrams of adapter circuits commonly required.—Sylvania Electric Products, Inc., Emporium, Penna.

T-460 FEED-WATER CONTROL. 16-page Bulletin 105-C illustrates and describes maker's 3-element air-operated feed-water control; discusses advantages, description of control system, operating features; contains charts and diagrams.—Bailey Meter Co., Cleveland 10, Ohio.

T-461 ENGRAVER. 2-page bulletin illustrates and describes maker's "Model 2D-4 Pantograph Engraver" for general 2-dimensional engraving.—H. P. Preis Engraving Machine Co., 651 State Highway 29, Hillside 5, N. J.

T-462 MICROSCOPE SPOTTING ATTACHMENT. 2-page Bulletin 183-50 and Price List 161-48 illustrates and describes maker's "M2001SA2" spotting attachment for toolmaker's microscope.—The Gaertner Scientific Corp., 1201 Wrightwood Ave., Chicago 14, Ill.

T-463 ELECTRICAL RESISTANCE TESTERS. 8-page Bulletin 21-85 illustrates and describes maker's "Megger" insulation tester and circuit testing ohmmeter; price list included.—James G. Biddle Co., 1316 Arch St., Philadelphia 7, Penna.

T-464 LOADING RESISTOR. 8-page Bulletin GEA-5515 illustrates and describes maker's loading resistor for testing diesel-electric locomotive power plants; discusses advantages, uses, ratings, and operating instructions.—General Electric, Schenectady, N. Y.

T-465 VOLTAGE RATIO DETERMINATION. Wallet size card illustrates and discusses maker's voltage ratio DB scale.—Ballantine Laboratories, Inc., Boonton, N. J.

T-466 INDUSTRIAL COUNTERS.—4-page Bulletin SK-22 illustrates and describes maker's "Silver King" industrial counters; covers features, price list and dimensional diagrams.—Production Instrument Co., 710 W. Jackson Blvd., Chicago 6, Ill.

T-467 INFRARED SPECTROPHOTOMETER. 28-page house organ, No. 12, 1951 issue of "What's New for the Laboratory," features discussion of spectrophotometer; illustrates and describes miniature pumps, tumbler-mixer, high-capacity condensers and adapters, "Almor" pyrometer, and thermoswitch controls.—Scientific Glass Apparatus Co., Inc., Bloomfield, N. J.

T-468 TIME INTERVAL METER. 4-page

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bulletin illustrates and describes maker's "Model 510" time interval meter; discusses basic design, operation, specifications and applications. —Berkeley Scientific Corp., Richmond, Calif.

T-469 CONTACT METER-RELAY. 2-page Bulletin CMR-7 illustrates and describes maker's "Model 451-C Sim-Ply-Trol" contact meter-relay for operation and process controls with electromagnetic locking contacts.—Assembly Products, Inc., Chagrin Falls, Ohio.

T-470 AUTOMATIC HEATING CONTROLS. 60-page 1951-52 Catalog contains data, installation helps, charts and diagrams.—Minneapolis-Honeywell Regulator Co., Minneapolis 8, Minn.

T-471 VOLTMETERS. 6-page catalog lists distributor's line of well-known a-c. voltmeters and ammeters, r-f. ammeters, d-c. voltmeters, milliammeters and ammeters, tachometers, and miscellaneous equipment; includes prices.— Maritime Switchboard, 336 Canal St., New York 13, N. Y.

T-472 THERMOREGULATORS. 12-page Catalog 18 illustrates and describes maker's mercury-actuated thermoregulators and thermostats; discusses operation, heating and cooling cycles and dimensions.—H-B Instrument Co., 2633 Trenton Ave., Philadelphia 25, Penna.

T-473 ACCELERATION-DISPLACEMENT RESPONSE. 4-page house organ, No. 19 issue of "SL Instrument Notes," features article "A Relation between Acceleration and Displacement Response."—Statham Laboratories, Inc. 12401 W. Olympic Blvd., Los Angeles 64, Calif.

T-474 ELECTRICAL MARKER. 6-page Bulletin B-1-51-5M illustrates and describes maker's "Panto Model UE and UE-2" utility engraver; "Model UEM" electrical marker and "Model UAM" acid etcher; discusses specifications of all "Panto" models.—H. P. Preis Engraving Machine Co., 651 State Highway 29, Hillside 5, N. J.

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